56TH CONGRESS, 2d Session. } HOUSE OF REPRESENTATIVES. { DOCUMENT No. 488.

DEPARTMENT OF THE INTERIOR

# WATER-SUPPLY

AND

# IRRIGATION PAPERS

OF THE

## UNITED STATES GEOLOGICAL SURVEY

## No. 45

WATER STORAGE ON CACHE CREEK, CALIFORNIA.—CHANDLER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1901

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

# WATER STORAGE

# CACHE CREEK, CALIFORNIA

BY

ALBERT E. CHANDLER

WASHINGTON

GOVERNMENT PRINTING OFFICE

1901

# CONTENTS.

# ILLUSTRATIONS.

# LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
*Washington, D. C., January 24, 1901.*

SIR: I have the honor to transmit herewith a manuscript prepared by Prof. Albert E. Chandler, of the University of California, giving the results of a study of the storage possibilities of Cache Creek Basin, California, and to recommend that it be printed in the series of Water-Supply and Irrigation Papers.

The investigations upon which this report is based are a part of a series carried on under the general direction of Mr. J. B. Lippincott, Mem. Am. Soc. C. E., resident hydrographer in California. Mr. J. H. Quinton, Mem. Am. Soc. C. E., has assisted, in the capacity of consulting engineer, in the preparation of the plans and estimates. For this survey financial assistance was rendered by the California Water and Forest Association and by the Woodland Chamber of Commerce. Field work consisted of a reconnaissance throughout the entire drainage basin—all localities being visited which were considered suitable for reservoir sites—and of measurements of the flow of the stream and its various tributaries. The time spent in the field was from June 21, 1900, when a start was made from Woodland, to July 28, 1900.

Eleven years prior to the time of this reconnaissance, or in 1889, a topographic map of Clear Lake and its outlet was made by the Irrigation Survey, the results of that survey being printed in the Thirteenth Annual Report of the United States Geological Survey, Part III, beginning on page 405. At a later period various power companies made studies of the outlet of the lake, and in 1888 the Southern Pacific Railroad made a preliminary survey from Rumsey up Cache Creek Canyon to the lake. A considerable portion of the data accumulated by those surveys has been assembled and employed in this report.

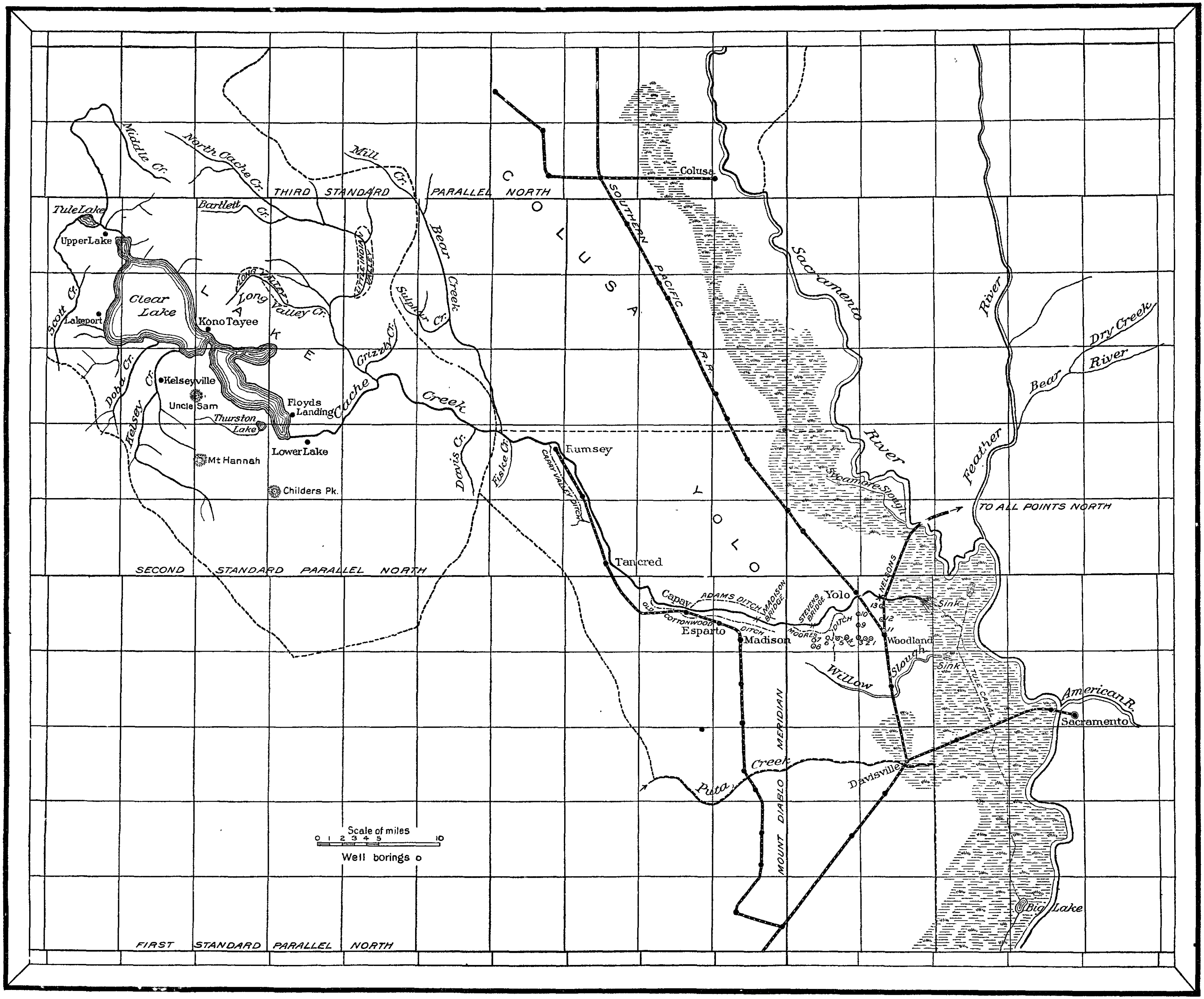
Acknowledgment is due to Mr. Ferdinand Formhalz, of the old Clear Lake Power Company; to Mr. Richard Wylie, of the new power company; and to the engineering office of the Southern Pacific Railroad Company, for assistance given. Thanks should also be extended to the many recorders of rainfall and lake levels who gratuitously

furnished what data they had, and to Mr. J. M. Wilson, of the United States Department of Agriculture, who, during the year 1900, made a thorough study of the water rights and the irrigation systems of Yolo County. Mr. Wilson kindly furnished the data bearing upon the pumping plants, as well as much information concerning the ditches herein described.

Very respectfully,

F. H. NEWELL,
*Hydrographer in Charge.*

Hon. CHARLES D. WALCOTT,
*Director United States Geological Survey.*




MAP OF CACHE CREEK BASIN.

# WATER STORAGE ON CACHE CREEK, CALIFORNIA.

By Albert E. Chandler.

## LOCATION AND PHYSICAL FEATURES.

Cache Creek, the only known outlet of Clear Lake, is situated in Lake County, California, about 75 miles north of San Francisco. From the lake the creek flows easterly to the corner of Lake, Colusa, and Yolo counties, thence across Yolo County to the sink 8 miles northeast of Woodland.

Fourteen miles from the lake the main stream is joined by the North Fork, often called Cache Creek. This branch drains the country to the north and east of the lake, and adds very materially to the drainage area of the creek, but it is much smaller than the stream from the lake and should be considered a tributary.

The drainage area of the main creek and its branches has been estimated by the California State engineering office as 1,192 square miles.

### TOPOGRAPHY.

The country in Lake County tributary to Cache Creek is exceedingly mountainous and rugged. The peaks to the north of Clear Lake rise to an elevation of 6,000 feet, and their slopes, as well as those of the lower ranges, may well be termed precipitous. Pl. I is a map of the basin. On the northern slopes of the ranges near the lake are magnificent belts of fir, white oak, and yellow pine. Elsewhere, however, the only evidence of vegetation is a dense growth of greasewood and chaparral. The interlaced branches of these shrubs make progress through them painfully difficult, but offer little resistance to escaping rain water.

From the lake Cache Creek flows through an open country for 5 miles, with a grade of 4.53 feet to the mile. It then follows Cache Creek Canyon for 25 miles. For the first 9 miles of its course through the canyon it has an average grade of 40.33 feet to the mile, varying from 20.41 feet to 137.94 feet. For the remaining distance the average slope is about 30 feet to the mile. A view of the bed of the creek at the head of the canyon is shown in Pl. II, *A*, and a view of the creek in canyon is shown in Pl. II, *B*.

The mountains which form the walls of the canyon rise several hundred feet above the stream, and in many places the immediate banks of the creek stand as perpendicular cliffs 300 feet in height. The bed is generally rendered very rocky by outcropping sandstone and serpentine and the resulting bowlders. At a few places in the canyon settlers have taken advantage of existing benches to raise small crops of corn and hay, but in no place is there a basin which might be used effectively for storage purposes.

After leaving the canyon the creek enters Capay Valley, in Yolo County, through which it winds for a distance of 28 miles, with a grade of 9.5 feet to the mile. Capay Valley is 20 miles long and from 1 mile to 3 miles wide. It is hemmed in on all sides by hills, to the shelter of which is due its remarkable productiveness. Once known merely as a rich wheat-raising district, it is fast becoming famous for its early fruits. All stone fruits seem to thrive there, and in the upper end of the valley even oranges are profitably cultivated on a small scale. From Capay Valley the creek enters the greater Sacramento Valley and flows, with a slope of 4 to 6 feet to the mile, to Tule Basin, bordering Sacramento River. There its natural channel ceases, and its waters enter a canal which connects the sink with the Tule canal. The latter was built by the State of California in 1864 to drain Tule Basin. It empties into Big Lake in the extreme southeast corner of Yolo County, and from the lake its waters reach the Sacramento through a slough.

The soil of Yolo Basin is for the most part a rich alluvial deposit, small areas of adobe being distributed with no uniformity. Mr. J. M. Wilson, of the Department of Agriculture, is of the opinion that "there are 75,000 acres of good fruit and alfalfa land about which there is no question as to the use of water. There is much more that, while it will not bear the reckless use of water, would, with proper drainage and care in application, be greatly benefited."

## PRECIPITATION.

Copies of all of the rainfall records kept in Cache Creek Basin were obtained and are given further on. Only one record of the North Fork region has been kept, and that for only the last three years. Short as that record is, however, it gives an excellent idea of extreme variation, since the precipitation for 1899 was almost as unusually large as that for 1898 was unusually small. Unfortunately, the records given are not all continuous. The missing records are as follows: 1888, 1889, and 1890 at Kono Tayee; 1887, 1888, 1890, 1893, 1894, and 1895 at Rumsey; and 1891 at Esparto. The averages would necessarily be changed somewhat were the records complete.

*A*. HEAD OF CACHE CREEK CANYON.

*B*. CACHE CREEK IN CANYON.

The table on the next page gives the elevation, the length of record, and the maximum, minimum, and average precipitation for each station. In fig. 1 is plotted the annual rainfall for Kono Tayee, Lakeport, Rumsey, Capay, and Woodland. The difference in the records for Kono Tayee and Lakeport is explained by their locations. Both are situated on Clear Lake, but the former is sheltered by the high bluffs

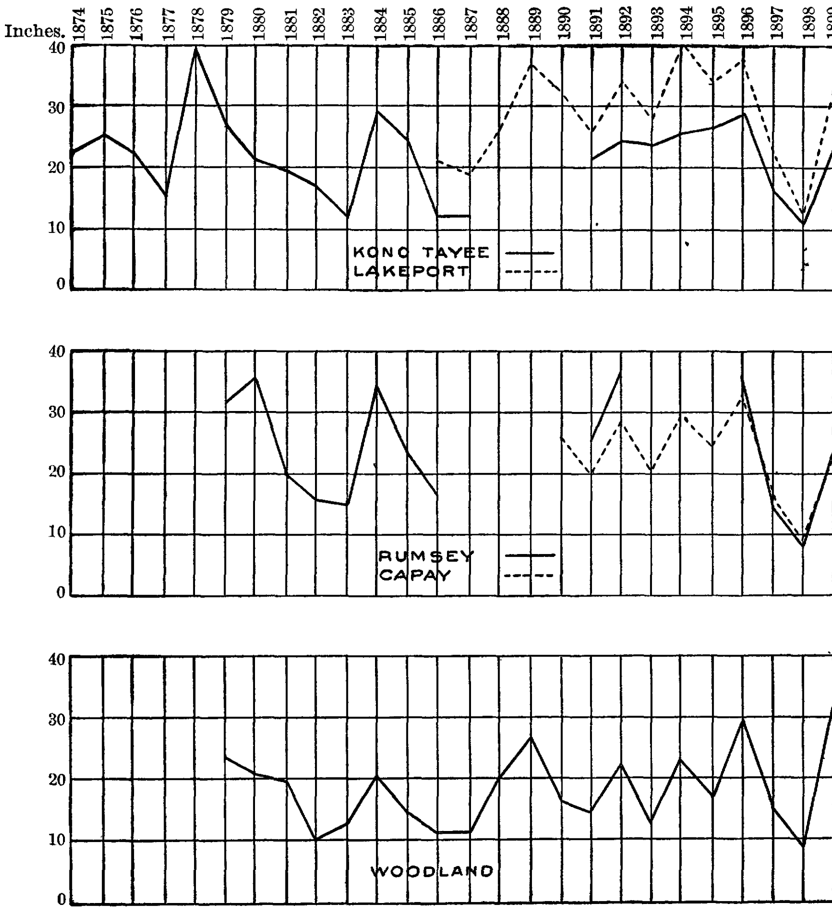



FIG. 1.—Diagram of annual rainfall at Kono Tayee, Lakeport, Rumsey, Capay, and Woodland.

at the narrow central portion of the lake, while the latter is fully exposed at the upper end. Rumsey is at the extreme head and Capay at the extreme foot of Capay Valley, and Woodland is in the lower end of the basin, near Sacramento River. Fig. 2 shows graphically the mean monthly precipitation for Kono Tayee, Rumsey, and Woodland.

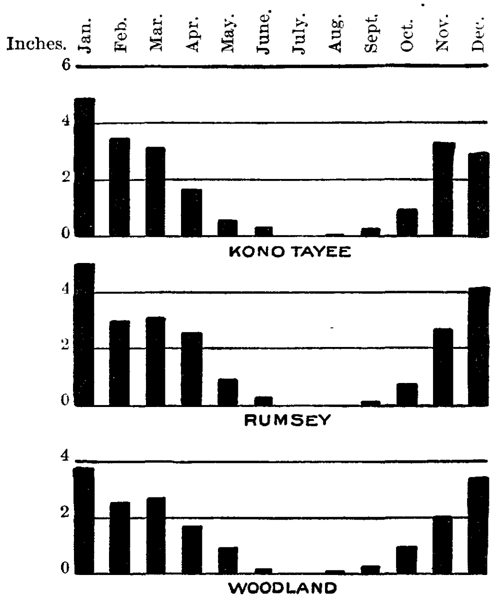



FIG. 2.—Diagram of mean monthly precipitation at Kono Tayee, Rumsey, and Woodland.

*Precipitation in Cache Creek drainage basin.*

| Station. | Elevation. | Length of record. | Maximum rainfall. | | Minimum rainfall. | | Average rainfall. | Estimated mean annual rainfall. |
|---|---|---|---|---|---|---|---|---|
| | | | Year. | Amount. | Year. | Amount. | | |
| | *Feet.* | *Years.* | | *Inches.* | | *Inches.* | *Inches.* | *Inches.* |
| Bartlett Springs | 2,340 | 3 | 1899 | 47.67 | 1898 | 17.35 | 29.71 | 38.62 |
| Lakeport | 1,335 | 14 | 1894 | 40.85 | 1898 | 13.50 | 28.81 | 29.57 |
| Kono Tayee | 1,325 | 23 | 1878 | 39.53 | 1898 | 10.89 | 21.66 | |
| Kelseyville | 1,425 | 6 | 1896 | 39.38 | 1898 | 14.73 | 27.04 | 26.85 |
| Rumsey | 425 | 14 | 1892 | 36.31 | 1898 | 7.96 | 23.92 | 24.58 |
| Capay | 220 | 10 | 1896 | 32.77 | 1898 | 8.68 | 22.79 | 21.73 |
| Esparto | 192 | 10 | 1896 | 28.45 | 1898 | 6.01 | 18.63 | 17.39 |
| Woodland | 63 | 22 | 1899 | 31.35 | 1898 | 9.00 | 18.25 | |
| Yolo | 79 | 6 | 1894 | 22.88 | 1898 | 5.32 | 16.99 | 14.83 |

The last column of the foregoing table gives the estimated mean annual rainfall at Bartlett Springs, Lakeport, and Kelseyville for a period of twenty-three years, and at Rumsey, Capay, Esparto, and Yolo for a period of twenty-two years.

*Monthly precipitation, in inches, at various places in Cache Creek drainage basin.*

BARTLETT SPRINGS.

[Observer, Bartlett Springs Hotel.]

| Year. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1897 | 3.50 | 6.78 | 5.36 | 0.75 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.70 | 2.31 | 3.72 | 24.12 |
| 1898 | 1.53 | 8.36 | 0.19 | 0.63 | 2.39 | 1.10 | 0.00 | 0.00 | 0.00 | 0.00 | 1.87 | 1.28 | 17.35 |
| 1899 | 13.14 | 0.00 | 8.49 | 0.85 | 2.47 | 0.00 | 0.00 | 0.00 | 0.00 | 4.79 | 10.06 | 7.87 | 47.67 |
| 1900 | 7.51 | 1.27 | 6.42 | 3.23 | 0.88 | 0.00 | 0.00 | 0.00 | | | | | |
| Average for 3 years | | | | | | | | | | | | | 29.71 |

*Monthly precipitation, in inches, at various places in Cache Creek drainage basin*—Continued.

LAKEPORT.

[Observers, A. M. Reynolds (1886-1899), Captain Rumsey (1888-1899), and Mr. Force (1893-1899).]

| Year. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1886 | 8.18 | 0.00 | 1.53 | 4.80 | 1.02 | 0.00 | 0.00 | 0.00 | 0.00 | 1.14 | 0.50 | 3.17 | 20.34 |
| 1887 | 1.48 | 8.19 | 1.89 | 2.57 | 0.20 | 0.11 | 0.00 | 0.00 | 0.14 | 0.00 | 1.16 | 3.03 | 18.77 |
| 1888 | 6.74 | 2.16 | 3.08 | 0.16 | 0.57 | 0.94 | 0.06 | 0.00 | 0.93 | 0.00 | 5.56 | 6.32 | 26.52 |
| 1889 | 1.36 | 0.46 | 8.70 | 0.88 | 2.91 | 0.16 | 0.00 | 0.00 | 0.00 | 8.16 | 3.74 | 11.60 | 37.97 |
| 1890 | 11.68 | 4.62 | 9.25 | 1.69 | 0.69 | 0.00 | 0.00 | 0.00 | 0.45 | 0.00 | 0.00 | 3.68 | 32.06 |
| 1891 | 1.14 | 10.91 | 1.32 | 2.26 | 0.80 | 0.50 | 0.00 | 0.00 | 1.04 | 0.25 | 0.28 | 6.70 | 25.20 |
| 1892 | 4.63 | 2.78 | 2.60 | 2.52 | 3.38 | 0.14 | 0.00 | 0.00 | 0.00 | 1.14 | 7.92 | 8.82 | 33.93 |
| 1893 | 3.49 | 5.67 | 6.78 | 2.22 | 0.76 | 0.00 | 0.00 | 0.00 | 0.68 | 0.69 | 4.42 | 2.80 | 27.51 |
| 1894 | 10.69 | 7.37 | 1.78 | 1.54 | 1.39 | 1.46 | 0.00 | 0.00 | 0.61 | 1.98 | 0.92 | 13.11 | 40.85 |
| 1895 | 15.66 | 4.01 | 4.01 | 1.16 | 1.39 | 0.03 | 0.01 | 0.00 | 1.15 | 0.01 | 2.02 | 4.10 | 33.55 |
| 1896 | 14.60 | 0.54 | 2.75 | 5.46 | 2.07 | 0.00 | 0.00 | 0.78 | 0.31 | 0.87 | 4.17 | 6.48 | 38.03 |
| 1897 | 3.45 | 7.92 | 4.50 | 0.44 | 0.07 | 0.69 | 0.02 | 0.00 | 0.05 | 1.61 | 1.63 | 2.07 | 22.45 |
| 1898 | 0.58 | 6.05 | 0.15 | 0.58 | 1.33 | 0.52 | 0.00 | 0.00 | 0.64 | 0.94 | 1.18 | 1.53 | 13.50 |
| 1899 | 8.69 | 0.04 | 6.53 | 0.49 | 0.44 | 0.38 | 0.00 | 0.03 | 0.00 | 4.07 | 6.57 | 5.47 | 32.71 |
| Average for 14 years | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 28.81 |

NOTE.—The figures for the years 1887 to 1892, inclusive, are the mean of two records; those for the years 1893 to 1899, inclusive, are the mean of three records.

KONO TAYEE.

[Observers, Captain Floyd and F. H. Porter.]

| Year. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1873 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 0.00 | 0.00 | 0.00 | 0.00 | ......... |
| 1874 | 1.88 | 3.60 | 4.62 | 2.05 | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 3.70 | 6.25 | 0.29 | 22.84 |
| 1875 | 9.16 | 0.38 | 0.92 | 0.00 | 0.84 | 0.42 | 0.00 | 0.00 | 0.00 | 1.17 | 6.98 | 5.12 | 24.97 |
| 1876 | 6.05 | 4.22 | 8.34 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 3.50 | 0.00 | 22.41 |
| 1877 | 3.17 | 2.81 | 1.40 | 0.50 | 0.00 | 0.50 | 0.00 | 0.00 | 0.73 | 1.65 | 2.23 | 1.98 | 14.97 |
| 1878 | 14.16 | 11.04 | 4.60 | 7.14 | 0.41 | 0.00 | 0.00 | 0.07 | 0.00 | 0.41 | 1.37 | 0.33 | 39.53 |
| 1879 | 3.01 | 3.41 | 9.15 | 0.47 | 0.64 | 0.00 | 0.00 | 0.05 | 0.00 | 0.91 | 3.57 | 5.72 | 26.93 |
| 1880 | 6.24 | 3.85 | 4.74 | 0.48 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.54 | 1.92 | 21.02 |
| 1881 | 5.50 | 6.58 | 0.64 | 0.95 | 0.12 | 0.25 | 0.00 | 0.00 | 0.00 | 0.63 | 2.90 | 1.77 | 19.34 |
| 1882 | 1.74 | 3.20 | 2.34 | 1.54 | 0.40 | 0.00 | 0.00 | 0.00 | 0.42 | 1.64 | 4.42 | 0.88 | 16.58 |
| 1883 | 1.40 | 0.60 | 3.81 | 0.95 | 2.41 | 0.00 | 0.00 | 0.00 | 0.70 | 0.99 | 0.39 | 0.70 | 11.94 |
| 1884 | 4.17 | 1.91 | 5.35 | 3.88 | 0.06 | 4.08 | 0.00 | 0.00 | 0.77 | 0.66 | 0.00 | 8.26 | 29.14 |
| 1885 | 1.47 | 0.51 | 0.00 | 1.70 | 0.00 | 0.43 | 0.00 | 0.00 | 0.63 | 0.23 | 15.37 | 3.51 | 23.85 |
| 1886 | 5.61 | 0.00 | 1.36 | 3.30 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | 1.05 | 0.19 | 0.63 | 12.75 |
| 1887 | 0.63 | 6.70 | 0.95 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.38 | 0.39 | 0.63 | 2.93 | 12.61 |
| 1888 | 5.84 | 1.20 | 2.75 | 0.04 | 0.00 | 0.38 | 0.00 | 0.00 | ...... | ...... | ...... | ...... | ......... |
| 1891 | 0.94 | 10.45 | 1.12 | 2.56 | 0.89 | 0.02 | 0.00 | 0.00 | 0.15 | 0.42 | 0.27 | 4.34 | 21.16 |
| 1892 | 2.46 | 2.13 | 2.68 | 1.97 | 1.37 | 0.62 | 0.00 | 0.00 | 0.00 | 0.84 | 6.53 | 5.57 | 24.17 |
| 1893 | 3.84 | 4.32 | 5.41 | 2.06 | 0.59 | 0.00 | 0.00 | 0.00 | 0.25 | 0.42 | 3.92 | 2.35 | 23.16 |
| 1894 | 6.92 | 4.32 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.63 | 1.22 | 0.74 | 10.81 | 25.55 |
| 1895 | 14.34 | 2.32 | 3.13 | 0.98 | 1.14 | 0.00 | 0.00 | 0.00 | 0.71 | 0.00 | 1.69 | 2.12 | 26.43 |
| 1896 | 9.42 | 0.25 | 2.31 | 4.62 | 1.72 | 0.00 | 0.00 | 0.28 | 0.29 | 0.73 | 3.34 | 5.93 | 28.89 |
| 1897 | 2.86 | 4.01 | 3.75 | 0.09 | 0.09 | 0.48 | 0.00 | 0.00 | 0.00 | 1.24 | 1.64 | 2.02 | 16.18 |
| 1898 | 0.71 | 3.99 | 0.11 | 0.64 | 1.67 | 0.44 | 0.00 | 0.00 | 0.51 | 0.46 | 1.15 | 1.21 | 10.89 |
| 1899 | 7.74 | 0.00 | 5.43 | 0.70 | 0.45 | 0.28 | 0.00 | 0.00 | 0.00 | 2.76 | 5.56 | 0.00 | 22.92 |
| 1900 | 3.10 | 2.17 | 2.89 | 2.32 | 0.67 | 0.00 | 0.00 | 0.00 | ...... | ...... | ...... | ...... | ......... |
| Mean for 23 years | 4.93 | 3.50 | 3.14 | 1.63 | 0.61 | 0.32 | 0.00 | 0.02 | 0.27 | 0.94 | 3.31 | 2.97 | 21.66 |

*Monthly precipitation, in inches, at various places in Cache Creek drainage basin*—Continued.

KELSEYVILLE.

[Observer, W. A. Maxwell.]

| Year. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1893 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 4.70 | 2.55 | ........ |
| 1894 | 10.30 | 6.28 | 2.57 | 1.15 | 1.05 | 1.20 | 0.00 | 0.00 | 0.52 | 1.28 | 0.87 | 12.88 | 38.10 |
| 1895 | 2.97 | 2.25 | 3.55 | 0.85 | 0.50 | 0.00 | 0.00 | 0.00 | 1.40 | 0.00 | 1.12 | 2.48 | 15.12 |
| 1896 | 15.37 | 0.96 | 1.87 | 6.01 | 0.65 | 0.00 | 0.00 | 1.30 | 0.43 | 1.08 | 4.50 | 7.21 | 39.38 |
| 1897 | 2.79 | 5.44 | 3.25 | 0.55 | 0.36 | 1.07 | 0.00 | 0.00 | 0.25 | 1.25 | 1.45 | 2.40 | 18.81 |
| 1898 | 0.60 | 5.61 | 0.00 | 1.88 | 1.64 | 0.40 | 0.00 | 0.00 | 1.00 | 0.95 | 1.15 | 1.50 | 14.73 |
| 1899 | 8.87 | 0.05 | 7.03 | 0.00 | 0.35 | 0.50 | 0.00 | 0.00 | 0.00 | 4.94 | 8.15 | 6.22 | 36.11 |
| 1900 | 4.52 | 1.37 | 4.99 | 3.03 | 0.17 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ........ |
| Average for 6 years | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 27.04 |

RUMSEY.

[Observers, Captain Rumsey (1878-1887) and Southern Pacific Railroad Company (1891-1899).]

| Year. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1878 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.26 | 0.30 | 1.20 | 0.10 | ........ |
| 1879 | 3.34 | 4.18 | 10.26 | 2.05 | 1.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 | 3.05 | 7.09 | 31.92 |
| 1880 | 4.57 | 1.30 | 2.73 | 10.74 | 1.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 15.51 | 35.91 |
| 1881 | 9.10 | 2.21 | 1.13 | 1.74 | 1.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.83 | 3.89 | 20.66 |
| 1882 | 2.64 | 3.85 | 3.40 | 1.22 | 0.13 | 0.04 | 0.00 | 0.00 | 0.18 | 0.84 | 2.90 | 0.57 | 15.77 |
| 1883 | 1.64 | 0.90 | 5.24 | 1.42 | 3.45 | 0.00 | 0.00 | 0.00 | 0.42 | 0.86 | 0.24 | 0.66 | 14.83 |
| 1884 | 5.64 | 3.19 | 7.11 | 4.83 | 0.32 | 3.03 | 0.00 | 0.00 | 0.27 | 0.83 | 0.00 | 9.33 | 34.55 |
| 1885 | 1.48 | 0.67 | 0.10 | 1.38 | 0.00 | 0.18 | 0.00 | 0.00 | 0.22 | 0.55 | 13.33 | 5.39 | 23.30 |
| 1886 | 7.85 | 0.04 | 1.16 | 4.17 | 0.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.69 | 0.04 | 1.56 | 16.16 |
| 1887 | 1.31 | 8.57 | 1.56 | 2.80 | 0.17 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ........ |
| 1891 | 0.87 | 13.60 | 1.16 | 1.92 | 1.28 | 0.00 | 0.00 | 0.00 | 0.85 | 0.00 | 0.35 | 4.98 | 25.01 |
| 1892 | 3.49 | 2.84 | 3.02 | 1.21 | 2.78 | 0.00 | 0.00 | 0.00 | 0.00 | 1.03 | 10.57 | 11.37 | 36.31 |
| 1893 | 4.80 | 5.42 | 5.77 | 1.76 | 0.77 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ........ |
| 1896 | 17.95 | 0.00 | 2.10 | 5.15 | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.82 | 5.45 | 35.92 |
| 1897 | 3.52 | 5.70 | 1.82 | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 1.40 | 0.00 | 1.00 | 13.74 |
| 1898 | 2.31 | 3.76 | 0.00 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.60 | 0.09 | 0.00 | 0.95 | 7.96 |
| 1899 | 7.15 | 0.00 | 4.75 | 0.00 | 0.56 | 0.28 | 0.00 | 0.00 | 0.00 | 2.90 | 2.57 | 4.62 | 22.83 |
| 1900 | 4.35 | 0.15 | 1.55 | 1.25 | 0.25 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ........ |
| Mean for 14 years. | 5.11 | 3.02 | 3.14 | 2.58 | 0.97 | 0.27 | 0.00 | 0.00 | 0.18 | 0.71 | 2.77 | 5.17 | 23.92 |

CAPAY.

[Observer, H. J. Taber.]

| Year. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1889 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 7.44 | 3.97 | 12.22 | ........ |
| 1890 | 10.39 | 4.41 | 4.43 | 0.88 | 1.62 | 0.00 | 0.00 | 0.00 | 0.40 | 0.00 | 0.00 | 3.50 | 25.63 |
| 1891 | 0.82 | 10.62 | 0.54 | 2.28 | 0.58 | 0.15 | 0.00 | 0.00 | 1.06 | 0.00 | 0.36 | 3.72 | 20.13 |
| 1892 | 3.02 | 2.76 | 2.29 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.97 | 9.88 | 9.22 | 28.57 |
| 1893 | 4.14 | 4.65 | 5.61 | 1.46 | 0.53 | 0.00 | 0.00 | 0.00 | 0.18 | 0.18 | 1.80 | 1.81 | 20.36 |
| 1894 | 7.04 | 2.86 | 1.11 | 0.74 | 1.70 | 0.39 | 0.00 | 0.00 | 1.75 | 1.58 | 0.44 | 11.79 | 29.40 |
| 1895 | 13.58 | 1.46 | 2.41 | 1.56 | 0.61 | 0.00 | 0.00 | 0.00 | 1.01 | 0.00 | 2.42 | 1.60 | 24.65 |
| 1896 | 14.31 | 0.09 | 2.71 | 6.60 | 0.57 | 0.00 | 0.00 | 0.41 | 0.50 | 1.49 | 3.13 | 2.96 | 32.77 |
| 1897 | 4.32 | 3.58 | 2.81 | 0.15 | 0.35 | 0.00 | 0.00 | 0.00 | 0.15 | 1.39 | 0.80 | 1.59 | 15.14 |
| 1898 | 0.67 | 4.07 | 0.00 | 0.38 | 0.71 | 0.00 | 0.00 | 0.00 | 0.88 | 0.50 | 0.26 | 1.21 | 8.68 |
| 1899 | 6.60 | 0.00 | 5.01 | 0.69 | 0.14 | 0.28 | 0.00 | 0.00 | 0.00 | 3.04 | 2.92 | 3.88 | 22.56 |
| 1900 | 3.50 | 0.30 | 2.07 | 1.00 | 0.64 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ........ |
| Average for 10 years | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 22.79 |

*Monthly precipitation, in inches, at various places in Cache Creek drainage basin*—Continued.

ESPARTO.

[Observer, Thomas Kennedy.]

| Year. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1888 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 0.57 | 0.00 | 0.48 | 5.40 | ........ |
| 1889 | 0.34 | 1.00 | 4.91 | 0.25 | 2.30 | 0.16 | 0.00 | 0.00 | 0.00 | 6.07 | 3.13 | 9.50 | 27.66 |
| 1890 | 7.38 | 3.77 | 3.47 | 0.85 | 1.38 | 0.00 | 0.00 | 0.03 | 0.32 | 0.00 | 0.00 | 3.02 | 20.22 |
| 1891 | 0.70 | 10.06 | 0.39 | 2.01 | 0.52 | 0.20 | ...... | ...... | ...... | ...... | ...... | ...... | ........ |
| 1892 | 0.00 | 1.70 | 1.63 | 0.56 | 1.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.26 | 5.61 | 17.44 |
| 1893 | 4.12 | 7.22 | 0.00 | 0.00 | 1.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.45 | 1.47 | 15.91 |
| 1894 | 4.47 | 2.01 | 0.67 | 0.38 | 1.36 | 0.68 | 0.00 | 0.00 | 1.10 | 1.40 | 0.22 | 8.26 | 20.55 |
| 1895 | 8.37 | 1.14 | 0.90 | 1.25 | 0.30 | 0.00 | 0.07 | 0.00 | 1.15 | 0.07 | 0.82 | 0.87 | 14.94 |
| 1896 | 12.69 | 0.00 | 1.75 | 4.41 | 0.60 | 0.00 | 0.00 | 0.60 | 0.54 | 1.38 | 3.36 | 3.12 | 28.45 |
| 1897 | 4.70 | 2.53 | 2.82 | 0.20 | 0.25 | 0.31 | 0.00 | 0.00 | 0.12 | 1.88 | 0.00 | 1.98 | 14.79 |
| 1898 | 0.92 | 1.50 | 0.16 | 0.23 | 1.14 | 0.00 | 0.00 | 0.00 | 0.43 | 0.27 | 1.36 | 0.00 | 6.01 |
| 1899 | 6.22 | 0.00 | 4.56 | 0.34 | 0.50 | 0.16 | 0.00 | 0.09 | 0.00 | 2.30 | 2.50 | 3.63 | 20.30 |
| 1900 | 3.81 | 0.29 | 1.59 | 0.94 | 0.65 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ........ |
| Average for 10 years | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 18.63 |

WOODLAND.

[Observers, Southern Pacific Railroad Company (1878-1899) and Elston drug store (1894-1899).]

| Year. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1878 | 8.17 | 8.36 | 3.83 | 1.47 | 0.65 | 0.00 | 0.00 | 0.00 | 0.17 | 0.22 | 0.89 | 0.42 | 24.18 |
| 1879 | 3.03 | 3.20 | 4.74 | 1.91 | 1.68 | 0.24 | 0.00 | 0.00 | 0.00 | 0.21 | 2.09 | 3.69 | 20.79 |
| 1880 | 1.04 | 1.60 | 0.93 | 6.96 | 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 8.77 | 19.71 |
| 1881 | 4.94 | 1.86 | 1.05 | 1.53 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.37 | 2.08 | 2.25 | 14.41 |
| 1882 | 0.89 | 1.88 | 1.89 | 1.37 | 0.00 | 0.00 | 0.00 | 0.00 | 0.59 | 1.38 | 2.40 | 0.51 | 10.91 |
| 1883 | 1.98 | 0.45 | 3.13 | 1.23 | 4.12 | 0.00 | 0.00 | 0.00 | 0.44 | 1.03 | 0.29 | 0.29 | 12.96 |
| 1884 | 3.47 | 3.24 | 4.69 | 3.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 4.63 | 20.86 |
| 1885 | 1.43 | 0.12 | 0.10 | 1.44 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 8.70 | 3.75 | 15.74 |
| 1886 | 4.78 | 0.00 | 1.31 | 4.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.29 | 11.48 |
| 1887 | 0.80 | 5.58 | 0.65 | 1.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 3.30 | 11.26 |
| 1888 | 4.20 | 1.27 | 2.38 | 0.10 | 1.10 | 0.00 | 0.00 | 0.00 | 0.56 | 0.00 | 5.57 | 4.97 | 20.15 |
| 1889 | 0.00 | 0.55 | 6.21 | 0.62 | 1.46 | 0.35 | 0.00 | 0.00 | 0.00 | 5.32 | 3.75 | 8.48 | 26.74 |
| 1890 | 5.10 | 2.40 | 3.35 | 1.00 | 1.60 | 0.00 | 0.00 | 0.00 | 0.60 | 0.00 | 0.00 | 2.35 | 16.40 |
| 1891 | 0.82 | 8.08 | 0.35 | 1.17 | 0.43 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 3.10 | 14.35 |
| 1892 | 2.05 | 2.73 | 2.14 | 1.28 | 2.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.57 | 5.47 | 6.10 | 22.56 |
| 1893 | 2.88 | 2.78 | 2.09 | 0.62 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 1.71 | 1.92 | 12.60 |
| 1894 | 4.12 | 2.15 | 0.88 | 0.42 | 1.49 | 0.77 | 0.00 | 0.00 | 0.85 | 1.12 | 0.85 | 10.82 | 23.47 |
| 1895 | 9.83 | 1.28 | 0.91 | 0.52 | 0.45 | 0.00 | 0.00 | 0.00 | 1.37 | 0.19 | 1.69 | 0.90 | 17.14 |
| 1896 | 11.87 | 0.11 | 2.08 | 6.73 | 0.76 | 0.00 | 0.00 | 0.35 | 0.50 | 1.27 | 3.76 | 2.03 | 29.46 |
| 1897 | 3.32 | 5.21 | 2.75 | 0.25 | 0.29 | 0.09 | 0.00 | 0.00 | 0.02 | 1.81 | 0.56 | 0.72 | 15.02 |
| 1898 | 0.43 | 3.35 | 0.12 | 0.21 | 1.38 | 0.18 | 0.00 | 0.00 | 0.35 | 0.98 | 0.47 | 1.53 | 9.00 |
| 1899 | 5.67 | 0.14 | 14.46 | 0.13 | 0.08 | 0.78 | 0.00 | 0.00 | 0.00 | 3.55 | 3.01 | 3.53 | 31.35 |
| Mean for 22 years. | 3.67 | 2.56 | 2.72 | 1.75 | 0.85 | 0.12 | 0.00 | 0.02 | 0.25 | 0.92 | 2.01 | 3.42 | 18.25 |

NOTE.—The figures for the years 1894 to 1899, inclusive, are the mean of two records.

*Monthly precipitation, in inches, at various places in Cache Creek drainage basin*—Continued.

YOLO.

[Observer, Yolo Orchard.]

| Year. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1893 | ...... | ...... | ...... | 0.55 | 0.78 | 0.00 | 0.00 | 0.00 | 0.06 | 0.10 | 1.56 | 2.06 | ......... |
| 1894 | 4.28 | 2.23 | 0.98 | 0.42 | 1.51 | 0.75 | 0.00 | 0.00 | 0.85 | 1.25 | 0.80 | 9.81 | 22.88 |
| 1895 | 9.10 | 1.48 | 1.15 | 0.61 | 0.41 | 0.00 | 0.00 | 0.00 | 1.59 | 0.30 | 2.07 | 1.03 | 17.74 |
| 1896 | 8.49 | 0.30 | 1.79 | 5.81 | 0.59 | 0.00 | 0.00 | 0.15 | 0.56 | 1.66 | 1.10 | 1.76 | 22.21 |
| 1897 | 2.56 | 4.04 | 2.11 | 0.31 | 0.26 | 0.20 | 0.00 | 0.00 | 0.07 | 1.35 | 0.39 | 1.25 | 12.54 |
| 1898 | 0.40 | 2.72 | 0.00 | 0.24 | 0.26 | 0.00 | 0.00 | 0.00 | 0.25 | 0.75 | 0.42 | 0.28 | 5.32 |
| 1899 | 5.81 | 0.00 | 3.97 | 0.36 | 0.32 | 0.80 | 0.00 | 0.09 | 0.00 | 3.23 | 3.59 | 3.09 | 21.26 |
| 1900 | 3.14 | 0.32 | 1.38 | 0.86 | 0.89 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ......... |
| Average for 6 years | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 16.99 |

## STREAM MEASUREMENTS.

Measurements were made of the discharge of all of the small streams in which water was flowing at the time they were visited. The flow of the main stream at its various junctions with other streams, was also recorded, to show the comparative value of the branches. During the latter part of July, 1900, a series of measurements was carried down Cache Creek from Rumsey. A similar series was made by Mr. Wilson a month earlier. The results of both series are given in the table on the next page. Mr. Wilson's measurements show a slight increase in discharge between Rumsey and Capay, but the records taken a month later show a gradual decrease.

Below Capay the creek widens until in some places its gravel bed is 1,000 feet from bank to bank. Above Woodland it narrows again to 100 or 200 feet, and flows between clay banks 30 to 50 feet high. Below Capay part of the flow sinks into the gravel, but it reappears again just above Moore's dam.

The measurements taken in July show discharges as follows: At Capay, 88.1 second-feet; opposite Madison, 54.6 second-feet; above Moore's dam, 69 second-feet. The last measurement taken was on July 24, at Stevens's bridge, 2 miles below Moore's dam. A half mile below the bridge the stream ceased to flow, leaving the gravel bed dry. A few miles farther down the creek water was found standing in pools, the underlying clay stratum having forced it to the surface; but whatever flow existed was within the gravel.

In the following table are recorded the results of the measurements of the main creek and its tributaries:

*Discharge measurements of Cache Creek and its tributaries.*

| Date. | Stream. | Point of measurement. | Hydrographer. | Area of section. | Mean velocity. | Discharge. |
|---|---|---|---|---|---|---|
| 1900. | | | | *Sq. ft.* | *Ft. per sec.* | *Sec.-ft.* |
| June 25 | Cache Creek | At Rumsey | A. E. Chandler | 78.3 | 2.413 | 189.0 |
| June 27 | do | At Bear Creek | do | 116.8 | 1.336 | 156.0 |
| June 29 | do | At North Fork | do | 68.4 | 2.360 | 161.4 |
| July 17 | do | At Clear Lake | do | 68.0 | 1.572 | 106.9 |
| July 20 | do | At Rumsey | do | 54.3 | 1.705 | 92.6 |
| Do | do | At Tancred | do | 43.0 | 2.079 | 89.4 |
| July 21 | do | At Capay | do | 57.9 | 1.522 | 88.1 |
| July 23 | Adams ditch | | do | | | 6.8 |
| Do | Cache Creek | At Madison | do | 35.9 | 1.521 | 54.6 |
| Do | do | At Moore's dam | do | 44.0 | 1.568 | 69.0 |
| July 24 | Moore ditch | | do | 73.1 | 0.676 | 49.4 |
| Do | Cache Creek | At Stevens's bridge | do | 22.7 | 0.899 | 20.4 |
| June 29 | do | At Rumsey | J. M. Wilson | | | 166.8 |
| Do | do | At Tancred | do | | | 167.5 |
| Do | do | Five miles above Capay | do | | | 173.6 |
| June 28 | do | At Capay | do | | | 161.6 |
| June 30 | do | At Esparto | do | | | 152.7 |
| Do | do | At Madison bridge | do | | | 140.9 |
| Do | Moore ditch | | do | | | 60.5 |
| July 3 | Cache Creek | At Stevens's bridge | do | | | 75.8 |
| Do | do | At Nelson's bridge | do | | | 53.0 |
| Do | do | At Cache Creek sink | do | | | 51.3 |
| Do | Tule canal | Opposite Woodland | do | | | 29.7 |
| Aug. 20 | Cache Creek | At Clear Lake | do | | | 39.6 |
| Aug. 27 | do | One-fourth mile above Rumsey. | do | | | 27.6 |
| June 29 | North Fork | At mouth | A. E. Chandler | 4.7 | 1.085 | 5.1 |
| June 30 | do | Above Long Valley Creek. | do | 4.8 | 1.333 | 6.4 |
| June 27 | Bear Creek | At mouth | do | 1.8 | 1.000 | 1.8 |
| June 30 | Long Valley Creek | do | do | 3.8 | 0.763 | 2.9 |
| Do | Wolf Creek | One mile above mouth | do | 0.5 | 1.000 | 0.5 |
| July 2 | North Fork | Above Bartlett Creek | do | 6.6 | 0.500 | 3.3 |
| Do | Bartlett Creek | At mouth | do | 1.9 | 0.737 | 1.4 |
| Do | Stanton Creek | do | do | 1.3 | 1.154 | 1.5 |
| July 8 | North Fork | At Little Indian Valley | do | 4.4 | 0.636 | 2.8 |
| July 12 | Scotts Creek | Eight miles above Clear Lake. | do | 0.8 | 0.625 | 0.5 |
| Do | Middle and Clover creeks. | Near Upper Lake | do | 2.1 | 0.714 | 1.5 |
| July 16 | Kelsey Creek | Two miles above Kelseyville. | do | 5.4 | 0.852 | 4.6 |

## IRRIGATION WORKS.

That water can successfully be diverted from Cache Creek is proved by the number of irrigating ditches that have been constructed in Yolo County. Only one, however, the Moore ditch, is of present importance. Two others, the Capay Valley ditch and the Adams ditch, are being used this summer (1900) on a small scale; that they are not in general use is due to protracted litigation over water rights, the common bane of irrigation throughout California.

## CAPAY VALLEY DITCH.

The first ditch, in point of position, to take water from Cache Creek is the Capay Valley. The diversion works (see Pl. III, *A*) are situated on the right bank of an old channel of the stream at the very head of Capay Valley. The ditch was begun in 1871, and about 12 miles were constructed before work was stopped permanently in the fall of 1873. The original plan was to irrigate all of Capay Valley on the south side of the creek (about 13,000 acres), but it is probable that not more than 8 miles of the canal were ever used.

It was started with a bottom width of 24 feet, but after the first half mile was narrowed to a width of 16 feet, and at the end of the third mile again contracted to 8 feet. The lower end of the ditch was widened to 10 or 12 feet on the bottom. Indeed the ditch seems to have been characterized by a total lack of system in its construction. The flumes, of which there are six, crossing small tributaries of Cache Creek, are quite as devoid of regularity as the dimensions of earthen channel. They are usually 4 feet deep and vary in width from 8 to 16 feet. They are constructed, strange to say, of Oregon fir throughout, a timber of great strength, but poorly adapted to structures which are alternately wet and dry. As a natural consequence, the flumes have decayed rapidly and are now wretchedly out of repair.[1]

At present (1900) the ditch beyond the first 3 miles is simply an undulation of the surface, and not a trace of the flumes described by Mr. Schuyler is to be found. Very little has been done with the ditch since 1886, when, after three trials in the lower courts, the supreme court affirmed a judgment "*forever* enjoining the company from taking water from Cache Creek at any and all times when such diversion would interfere with the flow of a sufficient quantity (432 cubic feet) in the Moore ditch." This summer (1900) the first 2 miles of the ditch were used by the fruit growers owning farms along it. They took turns in using the water, and in July, when the creek was low, by their combined efforts a diverting weir of brush, straw, and stones was thrown across the creek. No payment whatever is made by them to the company.

## TWO PROPOSED CANALS.

In the report just cited Mr. Schuyler describes a dam many of the timber bents of which still stand intact. He says:

In addition to the Capay ditch, the Clear Lake Water Works began another work, which, as projected, was the most comprehensive scheme for the disposal of the waters of Cache Creek ever attempted. It contemplated the construction of two large canals taking their head at a point some three miles above the village

[1] Report on the works and practice of irrigation in Yolo County, by J. D. Schuyler: Report of California State Engineer, 1880, Appendix E, p. 185.

*A.* DIVERTING WEIR OF CAPAY VALLEY DITCH.

*B.* DAM AND HEAD OF ADAMS DITCH.

of Capay; the one to irrigate the plains on the north of Cache Creek, the other to cover the lands south of that stream. The latter was to have been navigable and to extend to deep water in Suisun Bay or elsewhere. At the proposed head of the canal a dam was constructed six hundred feet in length. It was made prismoidal in form, 15 feet wide on top, with the upper slope of ½ on 1, and the lower 1 on 1. The south half of the dam was about 8 feet high and the north half about 13 feet. It was constructed of heavy timbers bolted to the sandstone rock which there cropped out in the channel, and the interior was filled with rock and gravel. The dam is reported to have cost $50,000. The canals were never begun. In all of these various improvements the Clear Lake Water Works have expended some $150,000, but thus far there have been few satisfactory results from their investment.

## COTTONWOOD DITCH.

Another ditch, not at present in service, is the old Cottonwood ditch, which heads on the south bank of Cache Creek, a half mile below the dam just described. It was commenced in 1864, and was ultimately extended a distance of 10 miles. The bottom width was 12 feet, the depth 5 to 5.5 feet, and the grade 3 feet to the mile. The original headworks were substantially built and advantageously located, but not a trace of them now remains. The ditch is said to have cost $50,000.

In 1879 the Capay Ditch Company succeeded the Cottonwood Ditch Company. In 1882 the Moore Ditch Company enjoined the Capay Ditch Company from using water from Cache Creek, and the lawsuit which resulted remained in the courts many years, but was never settled. In consequence, the legal status of the ditch was rendered so uncertain that it rapidly fell into disuse.

## ADAMS DITCH.

The Adams ditch diverts water from the north bank of Cache Creek less than a mile above Capay. Three miles of it were constructed in 1870, to irrigate 20 acres of Chinese gardens. In the following year the ditch was enlarged to a bottom width of 6 feet, a top width of 13 feet, and a depth of 2½ feet. In 1877–78 a new section was constructed and part of the old channel was abandoned. In 1882 the ditch was extended, under contract with the farmers above Cacheville (Yolo), to supply water to the old Cacheville agricultural ditch. The latter ditch was constructed in the winter of 1859–60, but has been abandoned since the destruction of its headworks by a flood late in the sixties. Just after the construction of the extension alluded to the Adams ditch became involved in the courts with the Moore ditch and the extension was never used. This summer (1900) the first 3 miles of the ditch were utilized to irrigate 60 acres of alfalfa and 20 acres of vegetables on the Adams place. The ditch has no headworks, the water being diverted into the open channel by a temporary dam of brush, straw, earth, and stones. (See Pl. III, *B*.) On July 23, 1900, there were 6.8 second-feet of water in the ditch.

## MOORE DITCH.

The Moore ditch, the oldest and most important ditch on Cache Creek, was built in 1856. It heads 8 miles above Woodland, and originally was 8 feet wide on top and 2 feet deep. In 1863 it was enlarged to a bottom width of 16 feet. In 1881 the grade was changed from 1.34 to 2.34 feet to the mile, and by extending the ditch upstream a gain of 10 inches in the fall was secured. At the same time a timber dam was constructed across Cache Creek, 24-foot piles being driven into the stream bed. Prior to the construction of this timber dam temporary dams of brush and earth were constructed as soon as the water became low in summer, but they were carried out by the first fall flood. The timber dam was swept away by the storm waters of 1889–90, and has not been replaced.

At present the main ditch and its branches have a total length of about 80 miles. The branches are under the management of subcorporations, the two most important being the South Fork Water Ditch Company and the Farmers' Irrigating Ditch Company. The ditch of the former was begun in 1864, and now has a length of 4 miles and a capacity of 40 second-feet. It is V-shaped, 20 feet wide on top, 4 feet deep, and has a grade of one-half foot to the mile. It has a capacity to irrigate 2,000 acres; it has irrigated 1,000 acres. The original cost was $2,400; but it could be constructed now for $800. The cost of irrigating varies from 50 cents to $2 an acre. The branch under the Farmers' Irrigating Ditch Company was also started in 1864. It is 1¼ miles long and controls 4 miles of laterals. The top width of the ditch is 16 feet, the bottom width 8 feet, and the depth from 2½ to 4 feet. Its capacity is 20 second-feet, and 1,000 acres are irrigated by it. The original cost was $2,400.

The maximum rate at which water may be sold is fixed by the board of supervisors of Yolo County at "$4 per foot for the period of 24 hours, with the water flowing in at the rate of 2 feet per second. * * * The measurements shall be made from the top of a weir 4 inches high, constructed in the bottom of the bulkheads where measurement is made, and over which weirs such water must flow."

Although a capacity of 432 second-feet is claimed for the Moore ditch, it seems impossible that it ever could have carried half that amount. The banks have been allowed to silt up, and now are covered by a luxuriant growth of water weeds, which necessarily reduces the efficiency of the canal to a minimum. The headworks are substantial and are admirably situated. (See Pl. IV, *A*.) It is said that even when the creek is dry through Capay Valley there is a supply at the headworks. It is deplorable that a durable diverting dam has not been built, for the temporary dam of earth and brush is not constructed until June, and as a result the farmers are not able to reap the benefits of late spring flooding.

*A.* HEADWORKS AND DAM OF MOORE DITCH.

*B.* HEADWORKS OF LANGENOOR DITCH.

## LANGENOOR AND HENNIGEN DITCHES.

Below the Moore ditch there are two private ditches—the Langenoor, which heads on the north bank of the creek a half mile below Nelson's bridge, and the Hennigen, located on the south side a mile above the canal connecting Cache Creek with the Tule canal.

Regarding the construction of the Langenoor ditch Mr. J. D. Schuyler writes:

The ditch was constructed and first used in 1864 to irrigate 20 acres of grain. * * * At its head there is an underlying stratum of clay in the creek bed, at a depth of but 4 feet, which brings water to the surface. To force all of the water to top a double row of sheet piling, about 40 feet apart and 100 feet long, has been driven into bed of creek, covered with a floor even with the surface. In connection with this arrangement was a low, movable dam, intended to be raised during low water and removed when the floods came.

A few of the upright posts of the dam and a part of the wooden floor now remain. At the head of the ditch is an old wooden head gate, or bulkhead, as it is called, which was constructed in 1877. (See Pl. IV, *B*.) It is 20 feet wide and 12½ feet high, and has two sets of gates (four gates in each set) 18 feet apart. The gates are made of 3-inch timber, and are 4 feet wide by 3½ feet high. In 1888 a wall of masonry 16 feet high was constructed across the ditch 140 feet from the old head gate, and the ditch between the two was lined with a wooden flume. Through the base of the masonry there are four channels, each 3.8 feet wide by 2.6 feet high, which are closed by means of wooden gates. The ditch is a half mile long, 24 feet wide on top, 10 feet wide on bottom, and 5 feet deep. In April, 1900, it was used to irrigate 100 acres of alfalfa and 70 acres of fruit. As the creek at this point is dry by the end of July, the ditch can be used only in spring and early summer.

The Hennigen ditch was constructed in 1887. It is 1 mile long, 30 feet wide on top, 10 feet wide on bottom, and 2½ feet deep. It has a capacity of 15 second-feet, and controls 700 acres, 200 of which it has irrigated. The original cost was $2,200; up to the present time $4,400 has been expended on it.

## PUMPING PLANTS.

Not being able to rely upon the irrigating ditches, many of the farmers about Woodland have resorted to pumping from Cache Creek and from wells. Now that their pumping plants are established, most of the operators find them so effective that they would hesitate to abandon them for even an improved system of ditches.

Outside of the vicinity of Woodland the only pump used for irrigation this season was one in charge of E. F. Hoswell, of Rumsey, in Capay Valley. The pump and engine are mounted on a wagon, and are moved from farm to farm as necessity requires. The engine is an 18-horsepower gasoline engine, known as the Hercules. Its cost was $1,000, and it uses 22 gallons of distillate, costing 10½ cents a gallon, in a working day of ten hours. The pump is of the centrifugal pattern, and has a capacity of 700 gallons a minute. Its cost was $150. Water is pumped directly from the creek and forced through 8-inch pipe to the field to be irrigated, and often it is elevated to a height of 55 feet. The average cost of operation is $1 an acre. A view of this portable pumping plant is shown in Pl. V, *A*, and a view of the pumping plant of Robert Morrison in operation on Cache Creek is shown in Pl. V, *B*.

In the Woodland district there are not fewer than twenty places where pumps are now used. Eight of these depend upon Cache Creek for their supply. As the pumping plants are all below Moore's dam, the supply is generally insufficient after the middle of July. When visited in the later part of July, 1900, the pumps on the creek could be used only a half day at a time. There was no water flowing in the creek, but long pools had formed where the water, percolating through the gravel, was forced to the surface. It was from depressions in these pools that the pumping was done, and when the supply was exhausted the pumps were stopped until the pool filled again. In some places earthen dams 1 foot or 2 feet high were thrown across the bed to hold the water, and small ditches were dug between the pools above to let more water down.

Those who use wells report an unlimited supply. In April, 1897, Mr. C. S. Mering pumped eighteen days and nights with a pump having a capacity of 3,000 gallons a minute, and noticed no diminution in the supply. Mr. R. B. Blower has used his well since 1879, and it has never failed to furnish a supply.

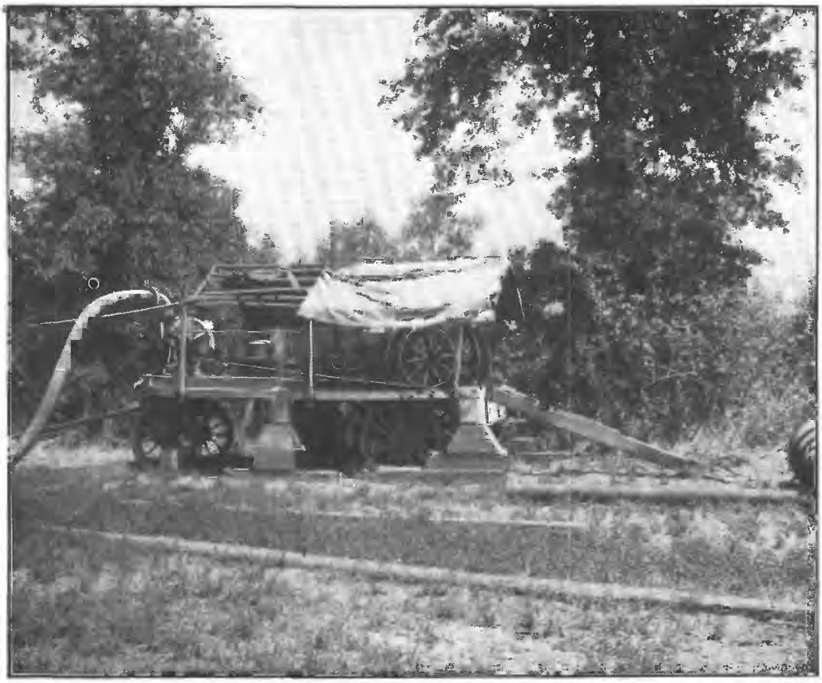
With the exception of the gasoline engine of Mr. S. V. Scarlet, all of the engines in use are steam engines. Straw, brush, wood, and coal are used for fuel. The average price paid is 75 cents a load for straw, $4 a cord for wood, $8.50 a ton for coal, and 11 cents a gallon for gasoline.

Mr. S. V. Scarlet's engine is portable, and is used by nine of his neighbors. In some cases the pumps are used to furnish water to fields adjacent to lands of the owner as well as to his own fields. The table in the following discussion on underground waters gives the more important details regarding these pumping plants.

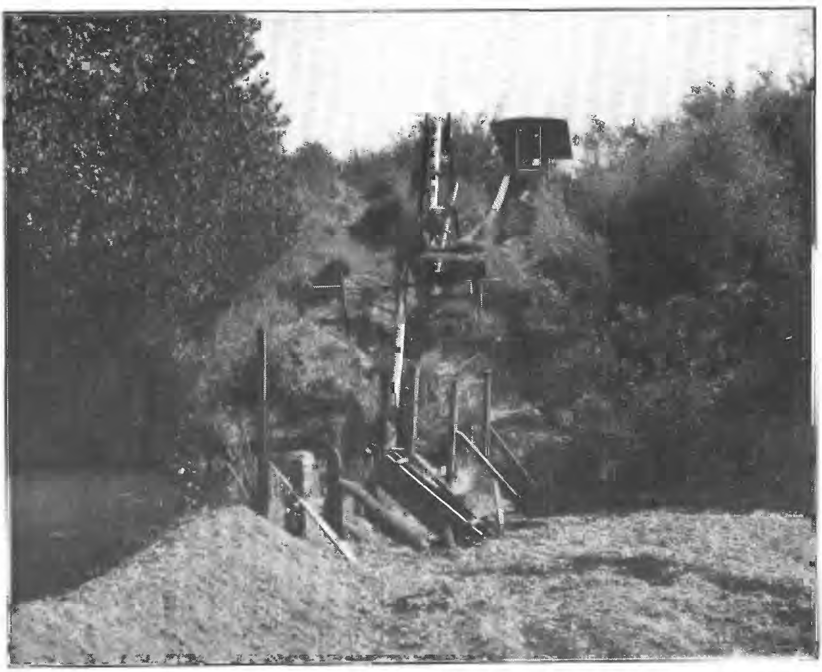
## UNDERGROUND WATERS.

### DEPTH OF WATER PLANE.

As may be seen in the following table, the depth at which water may be found at the pump sites varies from 10 to 25 feet. It is not unusual, however, for the depth at two points on a comparatively level farm to differ considerably more than this.



*A.* PORTABLE PUMPING PLANT IN CAPAY VALLEY.



*B.* PUMPING PLANT ON CACHE CREEK.

*Irrigation pumping plants in Woodland district.*

| Owner. | Source of supply. | Acres irrigated. | Size of well. Diameter. | Size of well. Depth. | Depth to water. | Height to which water is elevated. | Engine. Horsepower. | Engine. Cost. | Pump. Diameter. | Pump. Capacity. | Pump. Cost. | Operating expenses per acre.*c* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Ins.* | *Feet.* | *Feet.* | *Feet.* | | | *Ins.* | *Gallons per minute.* | | |
| Byron Jackson | 6 wells. | 160 | 8 | 78 | 18 | 18 to 44 | 60 | $1,600 | ---- | 3,000 | $500 | $1.50 |
| R. B. Blower | Well | 80 | 18 | 25 | 10 | 10 to 24 | 25 | 230 | 6 | 2,600 | ------ | .83 |
| J. R. Fisher | 3 wells. | 10 | {2–12, 1– 8} | 60 | 24 | 28 | 17 | *a* 600 | 6 | 1,800 | 213 | 3.20 |
| J. E. Scarlet | do | 80 | 12 | 42 | 16 | 28 | 25 | -------- | 8 | 2,000 | 214 | 1.50 |
| S. V. Scarlet | 2 wells. | 20 | 12 | 80 | 21 | 31 | 25 | 1,675 | 6 | 3,000 | 150 | 1.00 |
| C. H. Steinberg | do | 30 | 24 | 45 | 15 | 25 to 30 | 25 | *a* 700 | 6 | -------- | 160 | 1.57 |
| C. S. Mering | 3 wells. | 18 | 10 | 45 | 16 | 30 | 35 | ------- | 8 | 3,000 | 450 | .75 |
| F. Martinelli | do | 30 | 5 | ------ | 20 | 30 | 16 | 500 | ---- | -------- | ------ | 2.00 |
| L. Cramer | Well and Cache Creek. | 25 | 24 | 55 | 25 | 25 to 35 | 20 | 1,800 | 10 | 7,000 | 550 | .75 |
| O. J. Adams | Cache Creek. | 13 | ------ | ------ | ------ | 27 | 8 | 250 | ---- | 400 | 125 | .83 |
| Mrs. Peart | do | 70 | ------ | ------ | ------ | 20 | (*b*) | (*b*) | 12 | 5,000 | ------ | 1.20 |
| W. W. Nelson | do | 30 | ------ | ------ | ------ | 11 | 45 | 2,200 | 10 | 5,000 | 250 | 2.57 |
| F. Sanderson | do | 17 | ------ | ------ | ------ | 20 | (*b*) | (*b*) | 5 | 1,200 | 250 | 2.00 |
| Robert Morrison | do | 10 | ------ | ------ | ------ | 25 | (*b*) | (*b*) | 6 | 2,000 | 100 | 1.50 |

*a* Secondhand. *b* Use S. V. Scarlet's gasoline engine. *c* One irrigation.

This spring (1900) the firm of Botsford & Blithroad bored a number of wells along the roads leading from Woodland, for the use of watering carts. The depths to first water and gravel in thirteen of these are as follows:

*Well borings near Woodland.*

| Boring. | Depth to water. | Depth to gravel. |
|---|---|---|
| | *Feet.* | *Feet.* |
| No. 1 | 16 | 32 |
| No. 2 | 18 | 38 |
| No. 3 | 20 | 20 |
| No. 4 | 24 | 114 |
| No. 5 | 30 | 40 |
| No. 6 | 30 | 3 |
| No. 7 | 19 | ---------- |
| No. 8 | 19 | ---------- |
| No. 9 | 19 | 46 |
| No. 10 | 10 | 36 |
| No. 11 | 7 | 24 |
| No. 12 | 3.5 | 20 |
| No. 13 | 7.5 | ---------- |

In borings Nos. 7 and 8 no gravel was encountered, although the borings extended to a depth of 92 feet. The average depth to water of these 13 borings is 17 feet—a depth which the experience of other well borers has shown to be a good average for the irrigable lands about Woodland. In 1883–84 borings were made by engineers to determine the depth of the water plane through Hungry Hollow, a depression just northwest of Moore's dam, the results being submitted in the case of Moore *v.* Adams. The following depths have been taken from the profile of the 1884 borings, the lines starting at Cache Creek above Moore's dam and running 5 miles into Hungry Hollow:

*Borings to determine depth of water plane through Hungry Hollow.*

| Distance from creek. | Depth of water plane. |
|---|---|
| *Miles.* | *Feet.* |
| 1 | 14 |
| 2 | 14 |
| 3 | 16 |
| 4 | 19 |
| 5 | 23.5 |

NOTE.—The water plane was reported to be 1.2 feet higher in 1883 than in 1884.

## ARTESIAN FLOW.

There is only one artesian well in Yolo County. It is on the Dinsdale place, 1 mile east of Woodland. It has a depth of 134 feet and a diameter of 5 inches. When visited during the latter part of July, 1900, the discharge was very small, but it is said to be considerable during the wetter seasons.

## TRIBUTARIES IN CAPAY VALLEY.

The hills on the right and left of Capay Valley are cut up into a series of small canyons, with sharp ridges between. Consequently, the watersheds are so small and the slopes so steep that little or no water is to be found in the canyons after the rains have ceased. The most important of these are Rumsey Canyon, at the extreme head of the valley, and Cadenasso Canyon, near its foot, both on the west side. On June 23, 1900, there was a trace of a stream in the former canyon to a point 2 miles above its mouth, where the water sank, leaving the rest of the bed dry. During the summer water stands in small pools in Cadenasso Creek after it reaches the valley, the bed above being dry. The slope of the beds of both canyons is so great and the width so small that even if a sufficient drainage area existed they could not profitably be utilized for storage purposes.

### FISKE AND DAVIS CREEKS.

These creeks are usually marked on the maps of this region. Both enter the main creek, from the south side, in Cache Creek Canyon. Like the smaller streams in Capay Valley, they are dry soon after the last rains, and their beds remain dry washes until the next wet season.

### BEAR CREEK.

Other than the North Fork, the only tributary to Cache Creek of any consequence is Bear Creek, which enters the main stream on the north side, 5 miles above the mouth of the canyon. Twelve miles up the creek is Bear Valley, which has a length of 10 miles and an average width of 2 miles, and in which good crops of hay and grain are raised. Near the lower end of the valley the surface is undulating, and nowhere is there a good dam site, even if the great amount of water required to flood this large area were obtainable.

Below the valley there is very little open country, and for the last 5 miles the creek traverses a narrow canyon. Two miles below Bear Valley, Sulphur Creek empties into Bear Creek. Sulphur Creek drains a district in which three large quicksilver mines are operated, and many sulphur and mineral springs exist in its own bed. By the time it reaches Bear Creek it has dissolved so much mineral matter that it renders the water of the larger creek brackish and salty, unfitting it for irrigation purposes.

When measured at its mouth on June 27, 1900, Bear Creek had a discharge of 1.8 second-feet, while on the same day Cache Creek had a discharge of 156.0 second-feet. Bear Creek is said rarely to become dry. Even in the fall of 1898, when there was no outflow from the lake, water was running in this branch.

### NORTH FORK.

The North Fork of Cache Creek rises in the mountains north of Bartlett Springs. The region of its headwaters is famous for its many springs, the medicinal properties of which attract hundreds of visitors every summer. Bartlett Springs is situated on Bartlett Creek, which flows into the North Fork 3 miles below the springs. On July 2, 1900, there was a discharge of 1.4 second-feet in Bartlett Creek and a discharge of 3.3 second-feet in the North Fork at their junction. Seven miles below the junction the North Fork leaves the mountains and enters Little Indian Valley. As early as July 2, 1900, the stream in the upper part of the valley was dry, the water having sunk into the gravel floor. Two miles from the head of the valley rock outcrops in the stream bed, forcing the water to the surface. At that point Stanton Creek joins the North Fork. On July 2, 1900, Stanton Creek had a discharge of 1.5 second-feet, and on July 8 the discharge of the North Fork at the foot of the valley measured 2.8 second-feet.

At the foot of Little Indian Valley the North Fork enters a narrow canyon, through which it flows for a distance of 5 miles. A half mile below the lower end of the canyon Wolf Creek joins it. On June 30, 1900, the latter stream was dry, except for a few standing pools, for a distance of a mile above its mouth, at which point it had a discharge of 0.5 second-foot.

A mile below Wolf Creek and 7½ miles above Cache Creek is the mouth of Long Valley Creek. On June 30, 1900, this stream had a discharge of 2.9 second-feet. On the same day the discharge of the North Fork at that point was 6.4 second-feet.

Below Long Valley Creek there are no streams tributary to the North Fork. There are numerous canyons down which the storm waters rush after heavy rains, but none in which water can be found in the summer. The North Fork itself generally has no running water in its lower reaches after July. The water stands in pools, between which it seeps through the gravel. These pools remain throughout the dry season, and afford the only drinking water for the cattle in the neighborhood. For the last few miles the gravel floor is often 500 feet wide, and from it the greatly eroded clay banks rise to a height of from 50 to 100 feet. A view of these eroded clay slopes is shown in Pl. VI, *A*, and a view of the gravel bed of the creek in Pl. VI, *B*.

On June 29, 1900, the discharge at the mouth of the North Fork was only 5.1 second-feet, while on the same date the discharge of Cache Creek at the junction was 161.4 second-feet.

## RESERVOIR SITES ON NORTH FORK.

The only basins in the North Fork system which might be mentioned as reservoir sites are Twin Valleys, Little Indian Valley, and Long Valley.

The Twin Valleys are situated on a short branch of the North Fork a few miles north of Bartlett Springs. They are separated by a canyon a half mile in length. Each valley is three-fourths of a mile long and a half mile wide. As the narrow canyon could easily be dammed, the upper valley is an ideal site for a storage basin; but as the entire catchment area above the valleys is only 5 square miles, there would be very little water for storage purposes, and they can not, therefore, be recommended as reservoir sites. Both valleys are under cultivation, hay and garden produce for the hotels being raised, the vegetables being irrigated by water from the creek.

Long Valley is situated on Long Valley Creek, 2 miles from its mouth. It is 6 miles long, and has an average width of 1,000 feet

*A*. NORTH FORK OF CACHE CREEK, SHOWING ERODED CLAY SLOPES.

*B*. GRAVEL BED OF NORTH FORK OF CACHE CREEK.

and a grade of 25 feet to the mile. Although Rice's map of Lake County shows a drainage area of about 30 square miles, the run-off during the drier years, when water is most needed, is stated, on excellent authority, to be very small, as might be expected from experience elsewhere in the same region. Moreover, the valley at its foot, the so-called Narrows, is 700 feet wide. Even should an ample supply be assured, the cost of a dam across the Narrows would be almost prohibitive. There is some hay and grain raised in the valley, but the income of its residents is largely derived from stock raising.

Little Indian Valley, the only basin on the North Fork to be recommended as a reservoir site, is 5 miles long and averages from a half to three-fourths of a mile in width. Almost half of the entire area is under cultivation, but the soil contains so much gravel that the grain crops are very light. A small portion in the middle of the valley and near the creek is irrigated for vegetables, a temporary earthen dam being thrown across the stream at a point where the rock outcrops. A view of the valley looking toward the dam site is shown in Pl. VII, *A*, and views of the dam site are shown in Pls. VII, *B*, and VIII, *A*.

A reconnaissance survey of the valley was made to determine its approximate storage capacity, contours being located at intervals of 25 feet, up to the 100-foot level. The following table shows the acreage of each of the four planes, and the storage capacity, in acre-feet, at the intermediate layers, also the total capacity for each contour. The area of the 125-foot contour is estimated to be 1,500 acres, which is considered a minimum figure, as the valley widens very appreciably at its upper end.

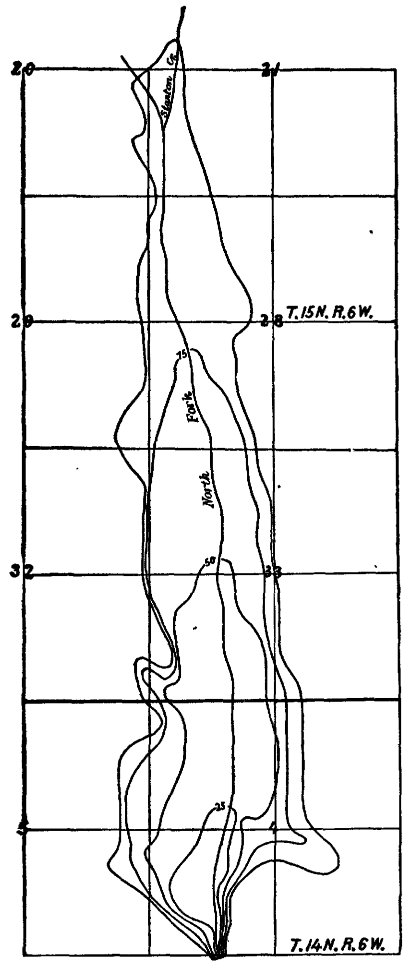



FIG. 3.—Map of Little Indian Valley reservoir site.

*Storage capacity of Little Indian Valley reservoir site.*

| Contour. | Area. | Capacity. | Total capacity. |
|---|---|---|---|
| | *Acres.* | *Acre-feet.* | *Acre-feet.* |
| 0 | 0 | | |
| | | 625 | 625 |
| 25-foot | 50 | | |
| | | 4,625 | 5,250 |
| 50-foot | 320 | | |
| | | 11,875 | 17,125 |
| 75-foot | 630 | | |
| | | 20,500 | 37,625 |
| 100-foot | 1,010 | | |
| | | 31,375 | 69,000 |
| 125-foot | 1,500 | | |

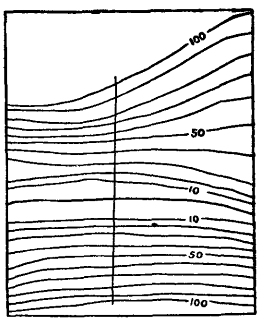



FIG. 4.—Map of Little Indian Valley dam site.

The only records of rainfall on the North Fork are those which have been kept for the last three seasons at Bartlett Springs. The precipitation for the season 1897–98 was 21.93 inches, which may be taken as the minimum. Rice's map of Lake County gives a drainage area of about 100 square miles above Little Indian Valley.

Using Mr. Lippincott's provisional curve for the run-off of central and southern California basins, the minimum precipitation of 22 inches should give a run-off of 16,000 acre-feet, and a precipitation of 38 inches—that estimated for this basin for a period of twenty-three years—should give a run-off of 58,000 acre-feet. To guard against a shortage in extremely dry years, however, a reserve of 29,000 acre-feet should be maintained during the years of average and excessive precipitation. On this basis an annual supply of 40,000 acre-feet would be available. The following table is based on the assumption that there were 29,000 acre-feet in the reservoir at the end of the irrigation season of 1885. Of the fourteen years considered, there would have been twelve years of full supply and two years of deficient supply. As experience shows that an occasional dry year may be tided over, it is believed that this site may be relied upon for 40,000 acre-feet.

*A*. LITTLE INDIAN VALLEY, LOOKING TOWARD DAM SITE.

*B*. LITTLE INDIAN VALLEY DAM SITE FROM ABOVE

*Table showing fluctuations in volume stored in Little Indian Valley reservoir.*

| Year. | Estimated rainfall. | Estimated run-off. | In reservoir at end of irrigation season. | Surplus. | Deficiency. |
|---|---|---|---|---|---|
| | *Inches.* | *Acre-feet.* | *Acre-feet.* | *Acre-feet.* | *Acre-feet.* |
| 1886 | 26.40 | 24,800 | 13,000 | | |
| 1887 | 24.35 | 20,700 | Empty. | | 6,300 |
| 1888 | 34.40 | 44,400 | 4,400 | | |
| 1889 | 49.20 | 124,400 | 29,000 | 59,800 | |
| 1890 | 41.60 | 73,200 | 29,000 | 33,200 | |
| 1891 | 32.70 | 39,750 | 18,750 | | |
| 1892 | 44.00 | 84,000 | 29,000 | 23,750 | |
| 1893 | 35.70 | 48,950 | 29,000 | 8,950 | |
| 1894 | 53.00 | 134,000 | 29,000 | 94,000 | |
| 1895 | 43.50 | 81,750 | 29,000 | 41,750 | |
| 1896 | 49.40 | 113,000 | 29,000 | 73,000 | |
| 1897 | 24.12 | 20,240 | 9,000 | | |
| 1898 | 17.35 | 7,525 | Empty. | | 23,475 |
| 1899 | 47.67 | 102,350 | 29,000 | 33,350 | |
| 1900 | 37.38 | | | | |

The canyon which leads from the valley (see Pl. VIII, *B*) is only 40 or 50 feet wide, and a shaly slate impregnated with quartz and some calcite outcrops on the bottom and on the sides to a height of 20 feet. At the point selected for the dam site the width between the canyon walls 100 feet above the creek bed is only 317 feet, and at 125 feet it is only 435 feet. On the west, immediately above the dam site, at a height of 600 feet, is a rocky point from which it is proposed to transfer the rock, by cable, to the dam. The elevation of the dam site is estimated to be 1,600 feet. Careful examination of the bed rock, with a diamond drill, should be made before the construction of the dam is begun.

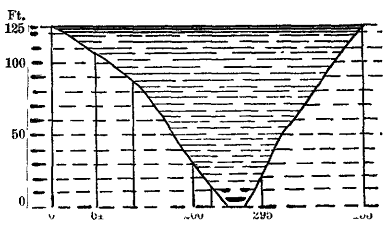



FIG. 5.—Elevation of Little Indian Valley dam site.

As the reservoir may be expected to fill during the wetter years, the dam must be an overflow weir. As designed, it will be 130 feet high, constructed of Cyclopean rubble, or of large blocks of stone set in concrete mortar, and adapted to withstand flotation effect with 10 feet of water passing over it. The cost is estimated at $433,000. Allowing $20,000 for the purchase of the necessary territory in the valley, the total cost of the proposed Little Indian Valley reservoir is estimated at $453,000, which is at the rate of $6.56 per acre-foot of total storage capacity, or at the rate of $11.33 per acre-foot of water available.[1]

[1] The calculations of reservoir capacity were based on a dam 125 feet high. As the height of the weir dam designed is 130 feet, the available storage capacity is increased at least 7,500 acre-feet. Forty-seven thousand and five hundred acre-feet may therefore be considered as the available supply, which reduces the cost per acre-foot to $9.54.

## CLEAR LAKE.

As has been stated, Clear Lake is situated on the Coast Range, 75 miles north of San Francisco. At mean low water the lake has a surface level of 1,325 feet above mean low water in San Francisco Bay. It is 20 miles long, 7 miles wide (greatest width), and has an area of 65 miles at its mean level. The greatest depth in the upper half of the lake is 35 feet, but in the lower portion there are small areas 50 feet deep. The drainage area is 417 square miles, and the storm waters are conducted to the lake through Scotts, Middle, and Clover creeks, at its extreme northwestern end, and by Doba, Kelsey, and Cole creeks on the southern side of its upper ends. These creeks are similar to others in Cache Creek Basin, in that they are torrential during the rainy season but are dry during the summer.

Middle and Clover creeks unite a mile below the town of Upper Lake. On July 12, 1900, their combined discharge was only 1.5 second-feet. Two miles above Clear Lake Scotts Creek flows into Tule Lake, a small, marshy depression, which it leaves through a slough. For 4 miles above Tule Lake the creek is simply a slough, and 6 miles above it had a discharge of 0.5 second-foot on July 12, 1900.

On July 16, 1900, Kelsey Creek had a discharge of 4.6 second-feet at a point 6 miles above the lake. A mile below, however, it had disappeared in its gravel bed. Doba and Cole creeks were both dry on that date. These three creeks flow through Big Valley, the largest and one of the most fertile in Lake County. Scotts Valley and the territory about Upper Lake are also remarkably productive, alfalfa being raised without irrigation. A good flow of artesian water is obtainable in the last-named districts at a depth of 75 feet, and it is now being used for irrigating vegetables.

In 1874–75 and in 1876–77 Clear Lake was one of the bodies of water examined by the engineers appointed to investigate the sources of water supply for the city of San Francisco. Recognizing the great loss due to evaporation over so extended an area, it was planned to "carry away the water from the lake in its season of abundance, and store it in a reservoir of less area and greater available depth. Such a reservoir exists on the adjoining stream to the south—Putah Creek, at Guenoc." This plan necessitated a tunnel 2.9 miles long. During these investigations (1874–1877) the water of Clear Lake was analyzed by four chemists. All were of the opinion that the water was entirely satisfactory for domestic purposes. On the next page is given the result of the analysis by Prof. Thomas Price.

*A.* LITTLE INDIAN VALLEY DAM SITE.

*B.* CANYON BELOW LITTLE INDIAN VALLEY DAM SITE.

*Analysis of water from Clear Lake.*

| | Grains per gallon of 231 cubic inches. |
|---|---|
| Carbonate of lime | 2.554 |
| Carbonate of magnesia | 2.683 |
| Carbonate of soda | .728 |
| Alumina and iron | .012 |
| Chloride of potassium | .261 |
| Sulphate of lime | .341 |
| Silica | .464 |
| Organic matter | 1.970 |
| Total | 9.013 |

As water may contain as many as 80 grains of soluble salts before reaching the danger point for irrigation purposes, it is certain that Clear Lake water is satisfactory.

## AREA AND VOLUME.

In 1889 the United States Geological Survey made a topographic survey of Clear Lake and its outlet. A datum plane was taken 1.27 feet above the low-water mark of 1873 and called 100. Mr. Wm. Ham. Hall compiled a number of tables for his report on this survey, the first four of which are given herewith.

The following table gives the area, in square miles, and the number of acres of each of the even-foot planes, from 90 to 110 feet—that is, 10 feet below and above the datum plane. The volume, in acre-feet, is also given for each 2-foot layer.

*Area and volume of Clear Lake.*

| Elevation of plane. | Area of plane. | Area of plane. | Volume. |
|---|---|---|---|
| *Feet.* | *Square miles.* | *Acres.* | *Acre-feet.* |
| 90 | 56.852 | 36,385 | |
| | | | 73,550 |
| 92 | 58.071 | 37,165 | |
| | | | 75,088 |
| 94 | 59.255 | 37,923 | |
| | | | 76,716 |
| 96 | 60.614 | 38,793 | |
| | | | 78,573 |
| 98 | 62.156 | 39,780 | |
| | | | 80,602 |
| 100 | 63.784 | 40,822 | |
| | | | 82,247 |
| 102 | 64.726 | 41,425 | |
| | | | 84,344 |
| 104 | 67.061 | 42,919 | |
| | | | 87,209 |
| 106 | 69.203 | 44,290 | |
| | | | 89,429 |
| 108 | 70.530 | 45,139 | |
| | | | 91,242 |
| 110 | 72.036 | 46,103 | |

The following table gives the equivalents of flow, in second-feet, corresponding to the several volumes in the successive 2-foot layers for 1 day, for 30 days, for 91 days, and for 182½ days, respectively:

*Table of equivalents of flow.*

| Volume of layers. | Equivalents, in second-feet. | | | |
|---|---|---|---|---|
| | 1 day. | 30 days. | 91 days. | 182½ days. |
| *Acre-feet.* | | | | |
| 73,550 | 37,081 | 1,236 | 407 | 203 |
| 75,088 | 37,857 | 1,262 | 416 | 208 |
| 76,716 | 38,677 | 1,289 | 425 | 212 |
| 78,573 | 39,614 | 1,320 | 435 | 217 |
| 80,602 | 40,637 | 1,354 | 447 | 223 |
| 82,247 | 41,466 | 1,382 | 456 | 227 |
| 84,344 | 42,522 | 1,417 | 467 | 233 |
| 87,209 | 43,968 | 1,466 | 483 | 241 |
| 89,429 | 45,087 | 1,503 | 495 | 247 |
| 91,242 | 46,017 | 1,534 | 505 | 252 |

## FLUCTUATIONS IN LEVEL.

In the following table is given the mean monthly and annual level of the surface of Clear Lake. The records up to 1888 were given to Mr. Hall by Captain Floyd, of Kono Tayee. The later records were obtained this summer (1900) from Mr. F. H. Porter, of Kono Tayee, and from Captain Rumsey and Captain Atherton, of Lakeport.

*Table showing mean monthly and annual level of Clear Lake, 1874–1900.*

| Month. | 1874. | 1875. | 1876. | 1877. | 1878. | 1879. | 1880. |
|---|---|---|---|---|---|---|---|
| January | 102.87 | 102.96 | 102.73 | 102.04 | 102.42 | .......... | 103.03 |
| February | 105.13 | 104.07 | 105.64 | 102.91 | 107.60 | 101.81 | 103.48 |
| March | 105.95 | 103.67 | 108.39 | 103.20 | 109.37 | 104.07 | 104.02 |
| April | 105.85 | 103.10 | 107.64 | 102.86 | .......... | 105.73 | 106.19 |
| May | 104.99 | 102.40 | 106.23 | 102.28 | .......... | 104.98 | 107.11 |
| June | 104.06 | 101.78 | 105.19 | 101.68 | .......... | .......... | 105.69 |
| July | 103.13 | 101.21 | 104.52 | 101.19 | .......... | 103.13 | 104.56 |
| August | 102.31 | 100.55 | 104.04 | 100.71 | .......... | 102.40 | 103.40 |
| September | 101.63 | 99.98 | 103.74 | 100.13 | .......... | 101.90 | 102.51 |
| October | 101.23 | 99.58 | 103.16 | 99.62 | .......... | 101.50 | 102.04 |
| November | 101.65 | 99.82 | 102.61 | 99.52 | .......... | 101.24 | 101.64 |
| December | 102.04 | 100.75 | 102.02 | 99.56 | .......... | 102.47 | 102.85 |
| Mean | 103.406 | 101.656 | 104.663 | 101.308 | 106.463 | 102.923 | 103.879 |

*Table showing mean monthly and annual level of Clear Lake, 1874–1900*—Cont'd.

| Month. | 1881. | 1882. | 1883. | 1884. | 1885. | 1886. | 1887. |
|---|---|---|---|---|---|---|---|
| January | 104.88 | 101.24 | 100.37 | 99.13 | 102.43 | 105.16 | ......... |
| February | 107.15 | 101.92 | ......... | 99.68 | 102.73 | 106.14 | 101.75 |
| March | 106.88 | 103.11 | 100.77 | 100.83 | 102.54 | 105.35 | 102.89 |
| April | 105.75 | 103.71 | 101.23 | 101.88 | 102.23 | 108.30 | ......... |
| May | 104.84 | ......... | 101.58 | 103.01 | 101.79 | 105.19 | 102.50 |
| June | 104.16 | ......... | 101.31 | 102.74 | 101.26 | 103.86 | ......... |
| July | 103.08 | ......... | ......... | 102.20 | 100.81 | 102.73 | ......... |
| August | ......... | ......... | 100.18 | 101.47 | 100.29 | ......... | 100.77 |
| September | 101.26 | 100.27 | 99.73 | 100.98 | 99.65 | ......... | 100.20 |
| October | 100.93 | 100.08 | 99.29 | 100.66 | 99.23 | ......... | ......... |
| November | 100.76 | 101.21 | 99.15 | 100.36 | 100.56 | ......... | ......... |
| December | 100.95 | 100.27 | ......... | 101.19 | 102.87 | 100.83 | 99.48 |
| Mean | 103.695 | 101.476 | 100.401 | 101.178 | 101.366 | 104.32 | 101.265 |

| Month. | 1888. | 1889. | 1890. | 1891. | 1892. | 1893. | 1894. |
|---|---|---|---|---|---|---|---|
| January | 99.83 | ......... | 111.31 | 101.08 | 101.35 | 104.56 | 104.40 |
| February | 101.73 | ......... | ......... | 102.81 | 101.73 | 106.52 | 105.33 |
| March | 102.45 | ......... | ......... | 104.02 | 101.73 | 107.35 | 106.31 |
| April | 102.27 | 103.53 | ......... | 104.09 | 102.15 | ......... | ......... |
| May | 101.96 | ......... | ......... | 103.52 | 102.33 | 104.73 | ......... |
| June | 101.36 | ......... | ......... | 102.37 | ......... | 103.46 | ......... |
| July | ......... | ......... | ......... | 101.56 | ......... | 104.48 | ......... |
| August | 100.08 | ......... | ......... | 100.81 | ......... | ......... | ......... |
| September | 99.84 | ......... | 101.86 | ......... | 100.16 | ......... | ......... |
| October | 99.57 | 100.53 | 101.48 | 100.23 | 99.73 | 100.93 | ......... |
| November | 99.34 | ......... | 101.07 | 100.01 | 100.23 | 100.54 | 100.15 |
| December | 99.83 | ......... | 100.97 | 100.56 | 104.47 | 101.40 | ......... |
| Mean | 100.751 | 102.03 | 103.34 | 101.91 | 101.54 | 103.77 | 104.05 |

| Month. | 1895. | 1896. | 1897. | 1898. | 1899. | 1900. | Monthly mean. |
|---|---|---|---|---|---|---|---|
| January | 109.90 | 100.56 | 102.62 | 100.20 | 98.66 | 102.00 | 102.74 |
| February | 109.00 | 105.40 | 104.73 | 100.54 | 99.32 | 102.09 | 103.72 |
| March | 106.96 | ......... | 105.63 | 101.00 | 99.45 | 102.94 | 104.12 |
| April | 105.73 | 104.98 | 105.52 | 100.73 | 100.40 | 102.92 | 103.81 |
| May | ......... | ......... | 104.35 | 100.40 | 99.84 | 102.29 | 103.32 |
| June | ......... | 104.50 | 103.15 | 99.98 | 99.69 | 101.57 | 102.66 |
| July | ......... | 103.46 | 102.32 | 99.46 | 99.42 | 100.82 | 102.24 |
| August | ......... | 102.34 | 101.42 | 98.73 | 98.88 | 99.98 | 101.08 |
| September | ......... | 101.36 | 100.73 | 98.20 | 98.25 | 99.40 | 101.24 |
| October | ......... | 100.88 | 100.20 | 97.84 | 97.92 | ......... | 100.32 |
| November | 100.23 | 100.59 | 99.96 | 97.75 | 98.21 | ......... | 100.30 |
| December | ......... | 101.32 | 100.09 | 97.86 | 99.57 | ......... | 100.92 |
| Mean | 106.36 | 102.54 | 102.56 | 99.39 | 99.13 | 101.55 | *a* 102.51 |

*a* Twenty-six years.

The table on the next page gives the extreme high-water levels and the extreme low-water levels of the lake for each year from 1873 to 1900 (compiled from the same records as the foregoing table), while fig. 6 shows graphically the same data. The number of feet fall in the lake during the year and the evaporation for the falling period are also given. The evaporation rate given is that used by Mr. Hall, who based it upon "observations made by the State Engineering Department on water surfaces exposed to similar conditions." The rate for the several months is as follows: January, 1.10 inches; February, 1.60 inches; March, 2.80 inches; April, 3.10 inches; May, 3.90 inches; June, 6.40 inches; July, 7.35 inches; August, 9.65 inches; September, 8.10 inches; October, 5.20 inches; November, 2.90 inches; December, 1.40 inches; total, 53.50 inches.[1]

*Table showing extreme high-water level and extreme low-water level of Clear Lake, 1873–1900.*

| Year. | High-water level. | | Low-water level. | | Fall in lake. | Evaporation. |
|---|---|---|---|---|---|---|
| | Month. | Elevation. | Month. | Elevation. | | |
| | | *Feet.* | | *Feet.* | *Feet.* | *Inches.* |
| 1873 | | | November | 98.73 | | |
| 1874 | March | 103.27 | October | 101.06 | 5.21 | 3.58 |
| 1875 | February | 104.25 | November | 99.40 | 4.85 | 4.09 |
| 1876 | March | 110.02 | January | 101.36 | 8.64 | 4.17 |
| 1877 | March | 103.29 | October | 99.42 | 3.87 | 3.58 |
| 1878 | March | 110.04 | January | 99.60 | 10.44 | 4.17 |
| 1879 | March | 105.96 | November | 101.21 | 4.75 | 3.91 |
| 1880 | April | 107.73 | November | 101.48 | 6.25 | 3.67 |
| 1881 | February | 107.90 | November | 100.73 | 7.17 | 4.09 |
| 1882 | March | 103.81 | November | 100.04 | 3.77 | 3.91 |
| 1883 | May | 101.77 | November | 99.12 | 2.65 | 3.38 |
| 1884 | April | 103.23 | December | 99.06 | 4.17 | 3.84 |
| 1885 | January | 103.67 | October | 99.06 | 4.61 | 3.87 |
| 1886 | January | 106.59 | December | 100.73 | 5.81 | 4.38 |
| 1887 | March | 103.07 | December | 99.47 | 3.60 | 4.08 |
| 1888 | March | 102.51 | November | 99.21 | 3.30 | 3.91 |
| 1889 | April | 103.53 | October | 100.53 | 3.00 | 3.57 |
| 1890 | January | 111.31 | November | 100.90 | 10.41 | 4.20 |
| 1891 | April | 104.12 | November | 100.00 | 4.12 | 3.67 |
| 1892 | May | 102.73 | November | 99.40 | 3.33 | 3.38 |
| 1893 | March | 107.35 | November | 100.48 | 6.87 | 3.91 |
| 1894 | March | 106.31 | November | 100.15 | 6.16 | 3.91 |
| 1895 | January | 109.90 | November | 100.23 | 9.67 | 4.20 |
| 1896 | February | 105.40 | November | 100.56 | 4.84 | 4.09 |
| 1897 | April | 105.81 | November | 99.90 | 5.91 | 3.67 |
| 1898 | March | 101.06 | November | 97.73 | 3.33 | 3.91 |
| 1899 | April | 100.73 | October | 97.90 | 2.83 | 3.57 |
| 1900 | March | 103.31 | | | | |
| Mean | | 105.25 | | 99.91 | | |

[1] The mean of four years' observations at Kingsburg, Fresno County, from 1881 to 1885, inclusive, as determined by the State engineering department, was 46.2 inches.

Although the annual rate of evaporation (53.5 inches) is less than has been observed at some points in California, it will be seen from an inspection of the foregoing table to be entirely too large, for in a number of instances the evaporation exceeds the actual fall in the lake. This could be accounted for by fluctuations in level after the lake began to fall, but no such fluctuations existed. Remembering that the summer flow of the tributary streams is practically nothing, it seems evident either that the rate used is much too high or that the lake receives large quantities of water from subterranean sources. As there are many springs in Soda Bay, at the upper end of the lake, and at Sulphur Banks, near the southern end, the latter condition is not improbable.[1]

The table on pages 34 and 35 shows the mean level of the lake for twenty-six years to be 102.51 feet, corresponding to a reading of 3.78

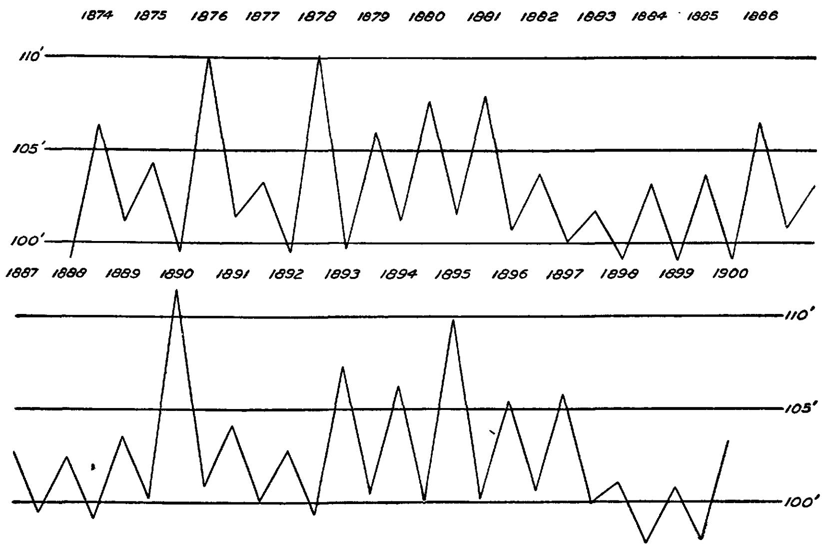



FIG. 6.—Diagram showing high-water and low-water levels in Clear Lake, 1874 to 1900.

feet on the gage rod at Kono Tayee. The mean obtained from the table giving the extreme high-water and extreme low-water levels of the lake is practically the same, being 102.58 feet.

## EFFECTS OF STORAGE.

It is the popular belief that Clear Lake can be used as a reservoir by simply arranging for the storage of 6 feet depth of water. This of course would be so if there were sufficient rain each year to keep the reservoir filled to that depth, but such is not the case. The watershed of the lake is so small and the surface exposed to evaporation is so great that a hold-over reservoir must be provided.

A careful study has been made to determine at what levels the lake should have been confined in order to allow the use of 80,000 acre-feet of water every year since 1873. To determine this question it was first necessary to estimate the amount of water entering the lake each year.

[1] The Geological Survey has established an evaporation gage in the lake, with Capt. D. C. Rumsey as observer, to determine accurately the amount of the evaporation.

For this purpose a provisional curve of run-off compiled by J. B. Lippincott from the data for a great number of California basins was used, but it was discovered that the results in many cases were less than the amounts shown to have entered the lake by the rise from extreme low water to extreme high water.

An inspection of the following table will show that the total amount calculated from Mr. Lippincott's provisional curve is too small in all cases where the rainfall is less than 19 inches and also in a number of other cases. Clearly, the so-called "intake" (the difference between extreme low water and extreme high water) is less than the volume which entered the lake, because it does not show either the discharge or the loss by evaporation during the time the level was rising.

*Table showing fluctuations in volume of Clear Lake.*

| Season. | Rainfall. | Run-off from 413 square miles. | Rainfall on lake. | Total increase in volume. | Intake. |
|---|---|---|---|---|---|
| | *Inches.* | *Acre-feet.* | *Acre-feet.* | *Acre-feet.* | *Acre-feet.* |
| 1873-74 | 14.6 | 16,930 | 49,080 | 66,010 | 279,300 |
| 1874-75 | 24.96 | 90,860 | 86,320 | 177,180 | 136,370 |
| 1875-76 | 37.0 | 223,020 | 128,650 | 351,670 | 458,650 |
| 1876-77 | 14.0 | 14,460 | 49,600 | 64,060 | 79,500 |
| 1877-78 | 54.0 | 586,660 | 186,750 | 773,410 | 458,650 |
| 1878-79 | 21.3 | 60,298 | 74,700 | 134,938 | 269,920 |
| 1879-80 | 29.0 | 115,640 | 102,960 | 218,700 | 362,720 |
| 1880-81 | 21.8 | 38,820 | 77,220 | 116,040 | 275,170 |
| 1881-82 | 16.7 | 28,910 | 58,100 | 87,010 | 127,570 |
| 1882-83 | 19.0 | 42,126 | 65,280 | 107,403 | 73,020 |
| 1883-84 | 24.3 | 93,340 | 81,600 | 174,940 | 164,900 |
| 1884-85 | 16.0 | 22,720 | 51,000 | 73,720 | 190,210 |
| 1885-86 | 35.5 | 198,240 | 124,500 | 322,740 | 316,900 |
| 1886-87 | 19.25 | 43,780 | 86,400 | 130,180 | 95,736 |
| 1887-88 | 17.88 | 35,100 | 61,350 | 96,450 | 123,480 |
| 1888-89 | 27.28 | 109,860 | 94,070 | 203,930 | 136,620 |
| 1889-90 | 51.43 | 536,900 | 182,300 | 719,200 | 474,360 |
| 1890-91 | 21.06 | 57,820 | 117,100 | 174,920 | 133,940 |
| 1891-92 | 24.32 | 85,080 | 83,000 | 168,080 | 111,700 |
| 1892-93 | 36.80 | 218,890 | 127,400 | 346,290 | 340,580 |
| 1893-94 | 32.82 | 165,200 | 112,050 | 277,250 | 248,170 |
| 1894-95 | 42.89 | 326,270 | 158,730 | 485,000 | 421,680 |
| 1895-96 | 33.48 | 169,330 | 116,200 | 285,530 | 219,410 |
| 1896-97 | 28.92 | 123,900 | 102,960 | 226,860 | 220,400 |
| 1897-98 | 14.57 | 16,930 | 48,960 | 65,890 | 89,570 |
| 1898-99 | 20.86 | 56,990 | 67,660 | 124,650 | 121,170 |
| 1899-1900 | 27.73 | 113,160 | 94,070 | 207,230 | 221,600 |
| Total | | | | 6,179,344 | 6,151,296 |

Neglecting the winter discharge and the winter evaporation, and considering the totals given at the bottom of the last two columns in the foregoing table, the run-off shown by Mr. Lippincott's provisional curve agrees with that indicated by the rise of the lake within one-half of 1 per cent. Thus the curve is shown to give an excellent conservative estimate for average conditions, and for that reason it was used in determining the run-off of Little Indian Valley.

The following table shows the method adopted to determine the limits for the hold-over reservoir:

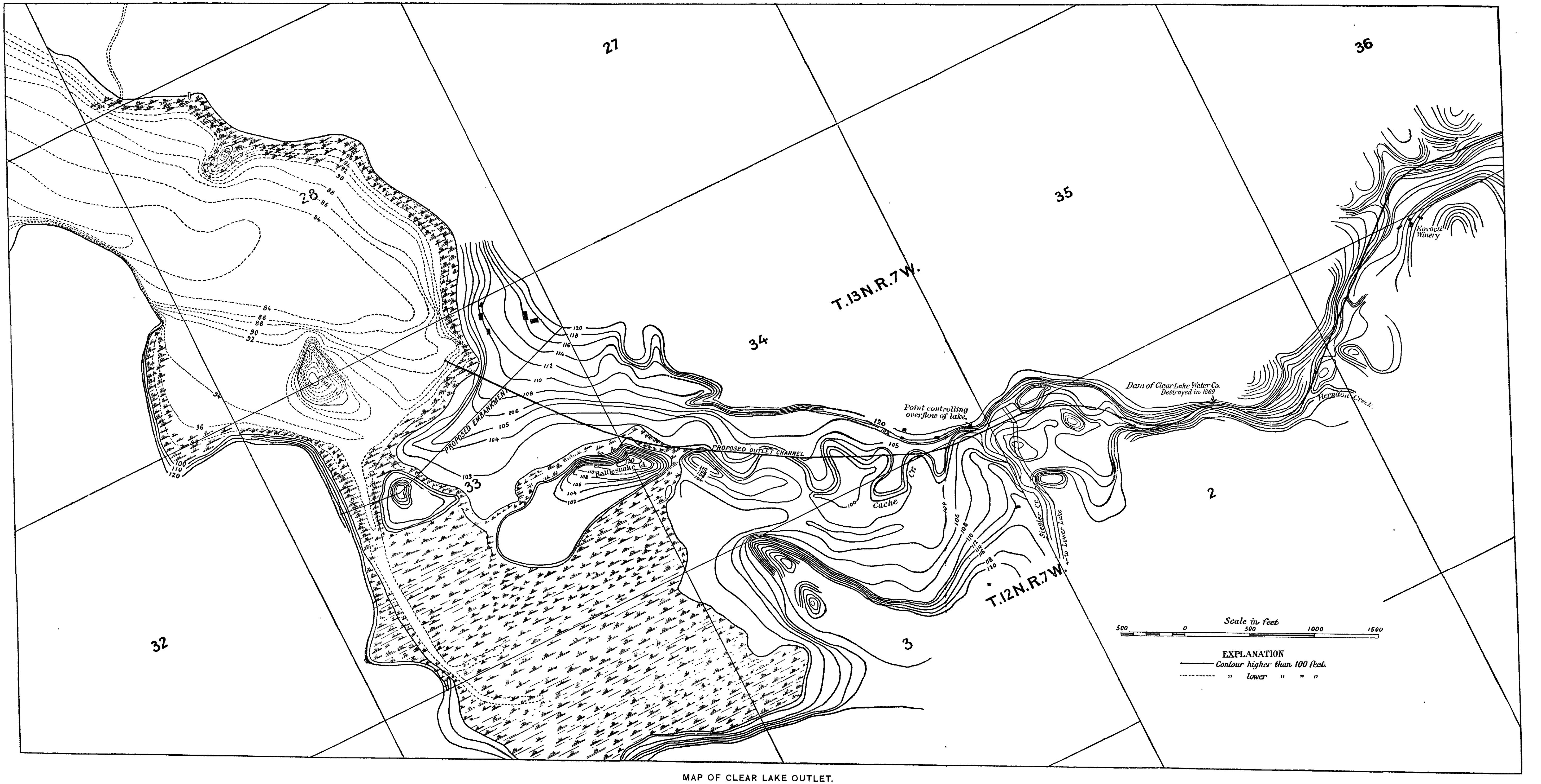
*Table showing fluctuations in Clear Lake.*

| Season. | Intake. | Resulting level. | Winter discharge. | Summer evaporation. | Working level. | Depth used. | Fall level. |
|---|---|---|---|---|---|---|---|
| | *Acre-feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* |
| 1873 (low water) | | | | | | | 98.7 |
| 1873-74 | 279,300 | 105.4 | 1.63 | 3.58 | 102.4 | 1.9 | 100.5 |
| 1874-75 | 136,370 | 103.8 | 0.76 | 4.09 | 100.5 | 2.0 | 98.5 |
| 1875-76 | 458,650 | 106.0 | 4.47 | 4.17 | 101.8 | 2.0 | 99.8 |
| 1876-77 | 79,500 | 101.7 | 0.29 | 3.58 | 98.4 | 2.0 | 96.4 |
| 1877-78 | 458,650 | 106.0 | 6.27 | 4.17 | 101.8 | 2.0 | 99.8 |
| 1878-79 | 269,920 | 106.0 | 0.84 | 3.91 | 102.1 | 1.9 | 100.2 |
| 1879-80 | 280,440 | 106.0 | 2.58 | 3.67 | 102.3 | 1.9 | 100.4 |
| 1880-81 | 275,170 | 106.0 | 3.08 | 4.09 | 101.9 | 2.0 | 99.9 |
| 1881-82 | 129,370 | 103.0 | | 3.77 | 99.2 | 2.0 | 97.2 |
| 1882-83 | 74,021 | 99.1 | | 2.65 | 96.5 | 2.0 | 94.5 |
| 1883-84 | 169,120 | 98.8 | 0.33 | 3.84 | 95.3 | 2.1 | 93.2 |
| 1884-85 | 190,210 | 98.1 | 0.74 | 3.87 | 95.0 | 2.1 | 92.9 |
| 1885-86 | 316,900 | 101.0 | 1.43 | 4.38 | 98.0 | 2.0 | 96.0 |
| 1886-87 | 95,740 | 98.4 | | 3.60 | 94.8 | 2.1 | 92.7 |
| 1887-88 | 123,480 | 95.9 | | 3.30 | 92.6 | 2.2 | 90.4 |
| 1888-89 | 177,740 | 95.2 | | 3.00 | 92.2 | 2.2 | 90.0 |
| 1889-90 | 474,360 | 106.0 | 6.21 | 4.20 | 101.8 | 2.0 | 99.8 |
| 1890-91 | 133,940 | 103.0 | 0.45 | 3.67 | 99.7 | 2.0 | 97.7 |
| 1891-92 | 111,700 | 100.5 | | 3.33 | 97.2 | 2.0 | 95.2 |
| 1892-93 | 340,580 | 103.6 | 2.96 | 3.91 | 102.1 | 1.9 | 100.2 |
| 1893-94 | 246,170 | 106.0 | 2.25 | 3.91 | 102.1 | 1.9 | 100.2 |
| 1894-95 | 421,680 | *a* 109.9 | 5.47 | 4.20 | 101.8 | 2.0 | 99.8 |
| 1895-96 | 219,410 | 105.0 | 0.75 | 4.09 | 101.7 | 2.0 | 99.7 |
| 1896-97 | 220,400 | 104.9 | 2.24 | 3.67 | 102.3 | 1.9 | 100.4 |
| 1897-98 | 49,260 | 101.6 | | 3.33 | 98.3 | 2.0 | 96.3 |
| 1898-99 | 121,170 | 99.3 | | 2.83 | 96.5 | 2.0 | 94.5 |
| 1899-1900 | 221,601 | 100.1 | | | | | |

*a* Maximum level.

Referring to the foregoing table, the "intake" is the increase in volume represented by the difference between the low-water and the high-water levels. By the "resulting level" is meant the height the lake's surface would attain after the addition of the intake to the previous low-water level. Thus, 279,300 acre-feet flowing into the lake when the level was 98.7 feet (the low-water mark of 1873) would cause a rise to 105.4 feet. The "summer evaporation" is taken from the table on page 36. The "winter discharge" is based on the assumption that as much water is discharged while the lake is rising as is discharged while it is falling through the same distance. As the outflow in the later fall months is very small, the periods of discharge may be taken as approximately equal and the element of time be eliminated. If there be any fluctuations in level while the lake is rising, which is far more probable than while it is falling, then the "winter discharge" must exceed the "summer discharge;" so whatever error there may be in the above assumption is on the side of conservatism. The "winter discharge" given in this table is, therefore, the "summer discharge" found by subtracting the evaporation given in the table on page 36 from the fall of the lake's surface given in the same table. In the cases where the evaporation is greater than the fall, nothing is allowed for the "winter discharge." The "working level" is found by subtracting the difference between the "winter discharge" and the "summer evaporation" from the "resulting level;" it represents the level at which the lake would stand in the fall were no water taken out for irrigation. As the top of the outlet weir is fixed at 106 feet, whenever the lake rises above that level the water is wasted. Accordingly, whenever the "resulting level," or the "resulting level plus the "winter discharge," is above 106 feet, the "summer evaporation" is subtracted from 106 feet, as it is at that point that the evaporation begins. The "depth used" shows the depth of reservoir necessary to store 80,000 acre-feet of water at the various levels. Subtracting the "depth used" from the "working level," the minimum "fall level" is obtained.

In the season of 1888–89, under our hypothetical conditions the lake would have fallen to 90 feet, and in the previous year to 90.4 feet. The next lowest levels would have been 92.7 feet and 92.9 feet, in the seasons of 1886–87 and 1884–85, respectively. Following our basis of calculation, to allow 80,000 acre-feet for each and every irrigating season the outlet of the lake should be fixed at 90 feet. As no "winter discharge" has been allowed for a number of seasons, and, furthermore, as it seems that the rate of evaporation used is too large, it appears almost certain that 100,000 acre-feet might have been used continuously for the last twenty-seven years. This is tantamount to claiming that with the weir height and outlet fixed at 106 feet and 90 feet, respectively, 100,000 acre-feet may safely be drawn from Clear Lake reservoir every season.




MAP OF CLEAR LAKE OUTLET.

In order to attack this problem more intelligently it is urged that provision at once be made to take measurements of the discharge and evaporation of the lake and the amount of rainfall on the higher altitudes in its drainage area. The only series of stream measurements that we have for the outlet of the lake were taken by one of the electric companies interested in the power proposition. These records seem so contradictory that no use has been made of them in this report. No records of evaporation of the lake have ever been kept, and all of the rain gages at present in use are at or near the lake level. A gaging station established below the outlet of the lake and one or two evaporation pans conscientiously attended would soon bring estimates of this nature from doubt to certainty.

## COST OF PROPOSED STORAGE WORKS.

On the map of the outlet made in 1889, a revision of which is shown in Pl. IX, the alignment for an outlet channel was projected, also that for an embankment at the lower end of the lake. Both of these alignments have been used in making the estimates for this report. Below is given an estimate on an outlet channel to carry 12,000 second-feet.

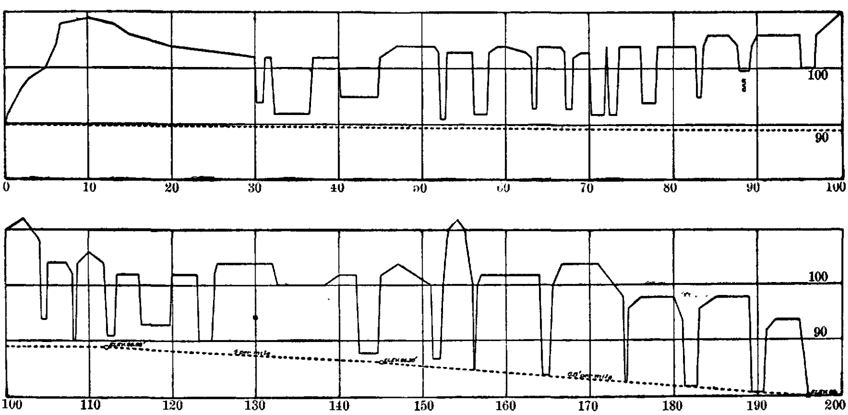



FIG. 7.—Profile of Clear Lake outlet channel.

*Data regarding proposed outlet channel of 12,000 second-feet capacity at Clear Lake.*

| Section. | Length. | Fall per mile. | Side slopes. | Bottom width. | Depth of water. | Excavation. |
|---|---|---|---|---|---|---|
| | *Feet.* | *Feet.* | | *Feet.* | *Feet.* | *Cubic yards.* |
| 1 | 11,200 | 0.53 | 2 to 1 | 220 | 16 | 1,302,396 |
| 2 | 3,300 | 4.00 | 2 to 1 | 140 | 12 | 231,828 |
| 3 | 5,100 | 6.60 | 2 to 1 | 100 | 12 | 479,141 |
| Total | 19,600 | | | | | 2,013,365 |

*Cost of outlet channel.*

| | |
|---|---|
| Dredging (10 per cent of excavation), 201,336 cubic yards at $0.35 | $70,468 |
| Cartage (10 per cent of excavation), 201,337 cubic yards at $0.17 | 34,227 |
| Excavation by wheel scrapers (80 per cent), 1,610,692 cubic yards at $0.10 | 161,069 |
| Total | 265,764 |

Referring again to the table on page 39, it will be seen that the greatest height which the water would attain was in 1894–95, when, if the whole amount had come from a single storm, the maximum level would have been 115.37 feet (109.9+5.47). As such a condition is not to be expected, the top of the embankment may safely be placed at

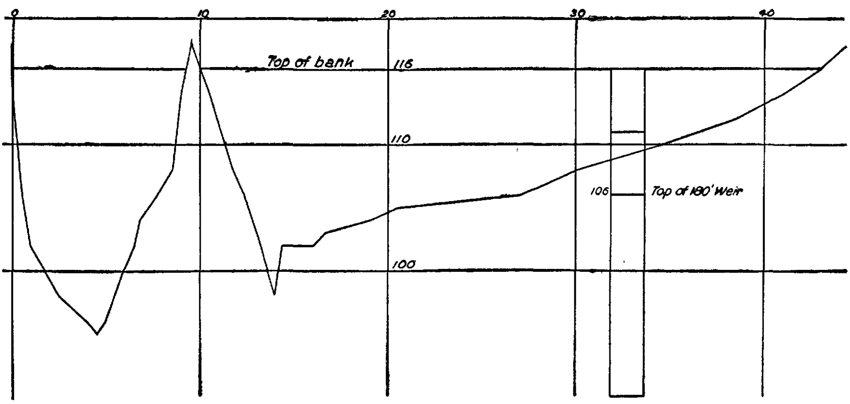



FIG. 8.—Profile of Clear Lake outlet embankment.

116 feet (10 feet above the level of the lake when full), which will allow a good margin for wave action. A profile of the embankment is shown in fig. 8. Following is the estimate on the embankment:

*Embankment for Clear Lake reservoir.*

| Length. | Top width. | Inner slope. | Outer slope. | Elevation of top. | Filling. |
|---|---|---|---|---|---|
| *Feet.* | *Feet.* | | | *Feet.* | *Cu. yds.* |
| 4,300 | 12 | 3 to 1 | 2 to 1 | 116 | *a* 66,878 |

*a* Includes 10 per cent for shrinkage.

The cost of the embankment would be $16,720—66,878 cubic yards of filling at 25 cents.

The outlet weir may safely be estimated at $50,000. It is based on a design for 18 concrete piers, with openings 4 feet wide and 16 feet deep, closed by specially designed iron-bound flashboards working in iron grooves in masonry. The entire structure is to rest on a grillage of timber 40 feet by 180 feet by 2 feet thick, the whole supported by 1,224 piles, driven at least 16 feet into the ground. A view of the regulating weir is shown in Pl. X.

The estimate also provides for heavy retaining walls of concrete resting on timber platforms on pile foundations.

The entire cost of the proposed works is as follows:

*Cost of proposed storage works at Clear Lake.*

| | |
|---|---|
| Outlet channel | $265,764 |
| Embankment | 16,720 |
| Riprapping | 50,000 |
| Outlet weir | 50,000 |
| Damages to property | 70,000 |
| Total cost | 452,484 |

Considering 80,000 acre-feet as the maximum storage capacity, the cost becomes $5.66 per acre-foot; but if we count upon 100,000 acre-feet (not an improbable figure) as the maximum storage capacity, the cost is only $4.52 per acre-foot.

These matters are more fully discussed in the appended report on the Clear Lake outlet, by Mr. J. H. Quinton.

## LANDS FOR RESERVOIR.

In the Eleventh Annual Report of the United States Geological Survey, Part II (Irrigation), pages 159 to 164, there is given a list of the segregations suggested in 1889 for the Clear Lake reservoir. Pl. LXXXV, page 151 of that report, is a map of this territory, the aggregate of which is 50,920 acres. Virtually all of the land recommended for segregation was taken up prior to 1889. The land on the immediate shore of the lake was necessarily sold in lots, the outer boundary being the meander shore line of the land survey. With the exception of small tracts taken up in 1890 and 1894, none of the land listed has been taken up since 1888. The purchase of 1890 is as follows:

SW. ¼ of NW. ¼ of sec. 20, T. 14 N., R. 8 W., M. D. M.

The land purchased in 1894 was taken up as California swamp and overflow land, and is as follows:

Lots 1, 2, 3, 4, and 5 (113 acres) of sec. 28, T. 14 N., R. 9 W., M. D. M.
NW. ¼ of NW. ¼ of sec. 33, T. 14 N., R. 9 W., M. D. M.

The following is a list of the remaining territory:

SE. ¼ of NE. ¼ of sec. 32, T. 13 N., R. 8 W., M. D. M.
S. ½ of NW. ¼ of sec. 36, T. 14 N., R. 8 W., M. D. M.
S. ½ of NE. ¼ of sec. 36, T. 14 N., R. 8 W., M. D. M.
NW. ¼ of sec. 36, T. 14 N., R. 9 W., M. D. M.
NE. ¼ of NE. ¼ of sec. 36, T. 14 N., R. 10 W., M. D. M.
W. ½ of SE. ¼ of sec. 36, T. 15 N., R. 9 W., M. D. M.
SE. ¼ of SW. ¼ of sec. 36, T. 15 N., R. 9 W., M. D. M.

Thus, out of the 50,920 acres recommended for segregation, 193 acres have been taken up since 1889, the date of the recommendation, and 520 acres still remain as public land. In considering this remainder, 520 acres, no account has been taken of the land which lies within the meander shore line.

## CLEAR LAKE OUTLET.[1]

In designing a regulating weir for the outlet of Clear Lake, Lake County, California, the following conditions had to be observed:

(1) To regulate levels of water between elevations of 90 and 106 feet above datum.

(2) To provide for measuring accurately the quantity of water to be delivered at any and all times during the irrigating season.

(3) To provide sufficient waterway over the weir, with all openings closed, to carry the greatest possible flood at full reservoir without raising the water to such a height as to inundate valuable lands adjacent to the lake.

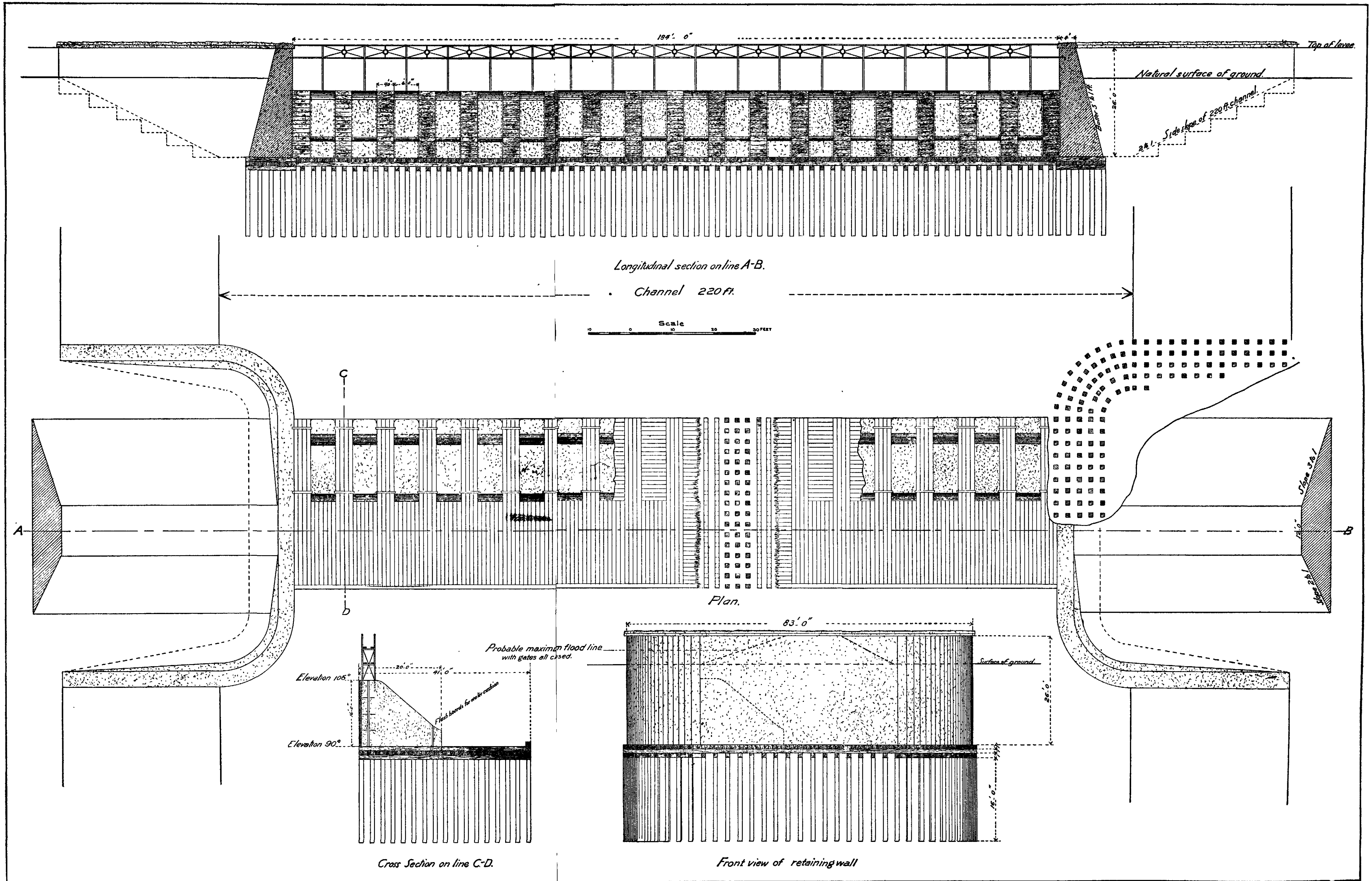
(4) To arrange the outlets so as to give the maximum delivery for minimum cost of construction and maintenance.

(5) To make gates so simple as to preclude their getting out of order.

As designed (see Pl. X), the weir consists of 18 piers of concrete, each 6 feet wide, 16 feet high, and 20 feet thick at base, with 19 openings, each 4 feet wide and 16 feet deep, closed by flashboards working in steel-lined grooves in the sides of the piers, the whole supported by a double grillage of 12-inch by 12-inch timbers resting on more than 1,200 piles. The ends of the weir are formed of heavy curved retaining walls of concrete, as shown in Pl. X. The curved portions of the retaining walls to be strengthened for tensile strains from the pressure of earth against the straight walls when the water is low, by embedding old steel cables or rods in the concrete around the curves and extending them into the straight walls at each end. The flashboards are 12 inches wide and 4 inches thick, and are bound with steel on the ends and sides, so as to fit accurately when dropped into place.

Through each flashboard two steel rods will be secured, so as to project about 1½ inches on each side of the board, to facilitate raising it when submerged. Suitable hooks attached to light chains can be dropped under these projecting rods, and in case of much pressure a small portable tripod with differential pulley attached may be set up on the footbridge, to start the flashboard from its seat. The footbridge (designed to afford access to the flashboards when the water is high) is supported on trestlework running across the top of the weir. The bents of this trestle are 10 feet apart, and are anchored in the tops of piers. When the water is low, the foot planks can be supported

[1] Report of J. H. Quinton.




ᴿEGULATING WEIR FOR CLEAR LAKE OUTLET.

on steel rods projecting from the upper sides of the piers. When the level of the water is at the top of the weir, the following amounts would flow through the openings:

*Discharge through weir openings.*

| Number of flashboards removed. | Discharge through 1 opening. | Discharge through 19 openings. |
|---|---|---|
| | *Cu. ft. per second.* | *Cu. ft. per second.* |
| 1 | 13.3 | 252.7 |
| 2 | 37.3 | 708.7 |
| 3 | 69.2 | 1,314.8 |
| 4 | 106.6 | 2,025.4 |
| 5 | 149.2 | 2,834.8 |

Assuming the duty of the reservoir to be 80,000 acre-feet annually, and that this amount will have to be delivered through the openings in 120 days (the length of the irrigating season), the amount of water which would have to be turned out daily during that time would be—

$$\frac{80{,}000 \text{ acre-feet}}{2 \times 120} = 333 \text{ second-feet.}$$

So that, except in case of a storm, it would seldom be necessary to remove more than two flashboards the entire length of the weir.

When the water is level with the top of the weir, the water pressure on the boards would be as follows:

First board, $4 \times 31.25 = 125$ pounds.
Second board, $4 \times 1.5 \times 62.5 = 375$ pounds.
Third board, $4 \times 2.5 \times 62.5 = 625$ pounds.

As the coefficient of friction for steel on steel is only 0.14, the pull required to move the third board would be only $0.14 \times 625$ pounds= 87.5 pounds, and this could easily be exerted without the aid of a pulley.

When the water is at the level of the top of the weir, the greatest pressure on the lowest flashboard is 4,000 pounds. Taken as a beam supporting this uniform load, the skin stress on the lumber would be only 750 pounds per square inch, a factor of safety of at least 7 for Oregon pine. Under similar circumstances the greatest pressure on a pier, including that on the flashboards on each side, would be $10 \times 16 \times 8 \times 62.5 = 80{,}000$ pounds, acting horizontally at one-third of the height of the pier from the base. The concrete in the pier measures 1,320 cubic feet and weighs approximately $1{,}320 \times 130 = 171{,}600$ pounds. With three flashboards removed from each opening and with 2,835 second-feet of water flowing into the lower channel, the depth of water here would be 6 feet; and if the water worked its way underneath, the pier might lose in weight about 45,000 pounds. When all of the flashboards are in place and 5 feet depth of water (6,832 second-feet) is flowing over the weir, the depth of water in the channel below would be 10 feet. Of course this would be an extreme case and one quite unlikely to occur if the flashboards were removed as the water rose, so as to keep the water as nearly at the level of the top of the weir as possible. In such a case, however, the piers would practically be submerged and would lose considerable of their weight, so that the possibility of their being moved bodily downstream had to be considered. To prevent this tendency, the piers are built on the first platform of 12-inch by 12-inch timbers, which is bolted to the caps on the piles. The second or upper platform of 12-inch by 12-inch timbers, which is securely bolted to the first platform, surrounds the piers on three sides, so that there is no possibility of the piers being moved downstream.

To prevent too much vibration from the water falling over the flashboards, secondary steel grooves are placed near the lower end of the piers, in which three or four flashboards may be dropped, so as to form a cushion for the falling water.

In order to keep the platform constantly wet during low water, which is essential to its preservation, a 12-inch by 12-inch timber is run the entire distance across its lower edge, being securely bolted to it with driftbolts. This forms a second cushion for the water flowing from the openings in the weirs, and also keeps the entire platform and piling continually submerged.

The measurement of any quantity of water during the irrigation season can easily be effected—(1) by removing the number of boards necessary to measure quantities greater than 13 cubic feet per second, and (2) by raising one flashboard, so as to form a submerged opening of the size required, to measure smaller quantities. It is evident that within reasonable limits this will afford a very effective and simple method of measurement.

It is proposed to run small horizontal grooves a few inches apart on the sides of the piers, so as to admit air under the jets falling over the flashboards.

It is believed that the weir as designed will meet all requirements.

# INDEX.

O